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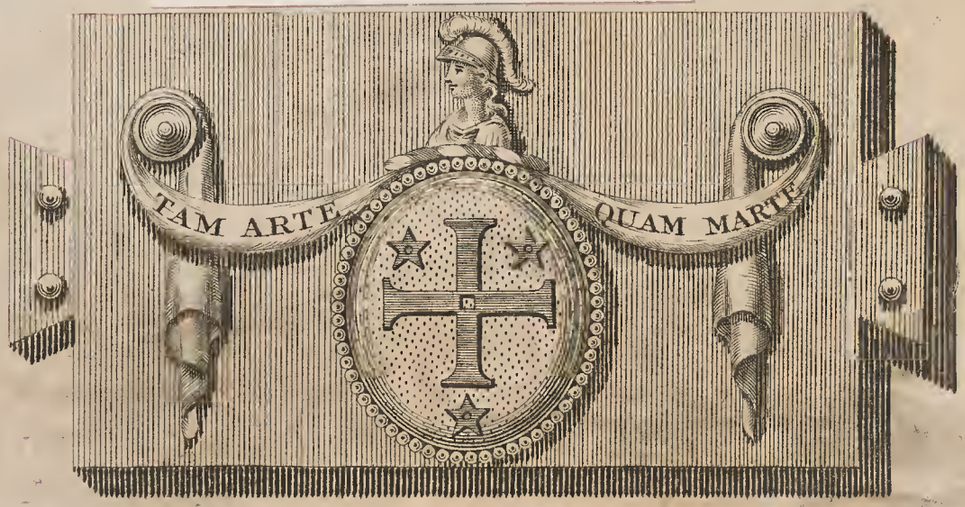

W. C. Mylne.

A Treatise of the motion of water, and other fluid bodyes

Part. I of many properties of fluid bodys of ye origene of fountains

Discourse I

of many properties of fluid bodyes.

The aire and flame are fluid bodys water, oyl mercury and other liquors, are fluid and liquid bodyes, every liquid is fluid but every fluid is not Liquid. I call that liquid, wch being in a sufficient quantity runs and extends it self below ye aire, till its upper surface be even, and because ye aire and flame have no such propertyes, I call them not liquid but onely fluid. heavyness and firmness are opposed to fluidity, that wch is heard amongst Iron and stones, can be difficultly seperated by other bodyes, and when they are seperated, ye seperated parts do not joyn together again: but on ye contrary fluid may easily be seperated but they forthwith reunite their seperated parts and in this it is that fluidity consists: so that wch is even and may be called fluid, but not Liquid because it doth not run but upon a plain, a little inclined, and when it fills a vessell its superiour parts are not even.

The water is indeed called humid by some Philosophers, but it is a property that wch is not in ye water that ought to be called humid, and in that sence ye aire is humid when it is much filled with aqueous vapours. dryness is opposed to humidity; and Linnen which called humid when it is wet, is called dry when ye water wch had wet it is evaporated.

The water doth receive successively different consistances of hardness, and liquidity: its naturall estate is to be ice, that is to say when no externall cause acts upon it, it remains firm and not liquid.

It becomes running and liquid by a moderate heat, and at ye same time some of its parts elevate themselves into vapours that is to say into many small drops seperated one from another, and of such smallness that you cannot at all perceive them. one may see it by experience when one cast a liquid cold into ye water, for one may see forthwith a thick fume elevate it self, but when it is much extended into its elevation and its small particles are seperated one from another they cannot any of them be perceived.

The vapours wch are thickned are sometimes visable and sometimes unvisable as their small particles are more or less minute or more less agitated, when they are visable and approach near ye earth, they are called mist, and when they are elevated on high they are called Clouds. there is more but they are never this less raised by a very small heat for to seperated from ye water vapours elevated by a greater heat then a meane; but there is none raised by a very small heat, for there are in a glass of ye water I have observed that two pounds of yet hearing in a very cold aire for a day have diminished of ye weight; from whence one may infer that water begining to freeze doth pursue some small heat, even as lead doth pursue much when it begins to harden it self after it is cast.

There are some strange and heterogenious parts in ye water, which transform themselves into aire with a great heat as one may by putting a vessell full of water upon ye fire for one shall see many small bubles of aire form themselves in a bottom of ye vessell and after that elevate themselves above ye water. one ought not to believe that they proceed from ye flame which passeth under ye vessell seeing that oyl doth not raise any such bubles of aire, when you let it be a small time even ye fire to evaporate what is aqueous, although one augments ye fire.

there form also like bubles in water when it freezeth: and because ye heterogenious matter wch I call aëreing occupies greater place when it is reduced into bubbles of aire, it endeavours to extend it selfe, and being not able to pass through ye ice, it breakes it and also ye vessell wch if it is narrower at ye top than towards ye middle.

To explain how it comes to pass that ye matter wch is in ye water possesseth a greater place when it is reduced to aire: we must suppose that ye aire is a mass of infinite small filaments interwoven and next one with another like ye smale filaments of cotton. now if you dip into a glasse half full of water a mass of purest cotton it will in ye beginning possess a greater place proportionable to its bulk, and will considerably elevate ye water towards ye top of ye glasse, but if you seperate by little and little ye small filaments of ye cotton so that ye water may run be-twixt them, then ye upper surface of ye water descends by little and little to ye same mark where it was when you put into ye cotton.

By this experiment you may know that ye aire doth insinuate it selfe by little and little into ye water and that it possesseth much less place than when it is in small bubbles, and before it is mixed and as it were absorbed by ye water, it is reduced into small bubbles by ye motion wch heat or some other cause gives it, and possesseth much more place than before.

That ye aire doth insinuate it selfe into water may be known by ye following experiment. Boyl water ye space of two hours and when it is cold, fill with it a small glasse bottle, stop ye neck with your fingers and immerge it into a glasse full of water with its necke downwards in such sort that there may be about ye quantity of a hazel nut of ye grosse aire: you may observe that in 24 hours that aire will disappear. but in like manner another bubble of aire as grosse, it also will enter by little and little into ye water but it will require more time to absorb it entirely: one may make also several others of ye same thickness to enter one after another: but at last when ye water is sufficiently impregnated no more will enter, and a small bubble of aire of two lines diameter will keep its selfe above ye water in ye bottle without entering, 2 or more than 15 days. this effect is yet more remarkable in spirit of wine, for if you put into a wind pump a glasse half full after you have pumped a good part of ye inclosed aire into ye recipient there will come out a great quantity of this aëreing matter in grosse bubles; but in a little while there will will no more come out. and if you fill a small bottle with that spirit of wine from which ye aëreing matter is seperated, and then permit ye grosse aire to enter and about an inch to stay on ye top of ye bottle after it has been wrought into it spirit of wine, as was above said of boyled water, that aire will insinuate it selfe into ye spirit of wine in less than two hours: and if you do 3 times you put a like quantity it will also enter; but if you that bottle into ye aire pump that aire as it is dissolved and mixed invisably with ye spirit of wine, will come out in grosse bubles as soon as you have have pumped a little of ye aire in ye recipient wch manifests that it is that aire that comes out of ye water and many other liquors when they freeze, boyl, or when any spring of ye aire which puffes them is a little diminished by ye wind pump which I explain more fully in ye treatise of ye air of ye aire.

I shew what happens to water when it freezeth by ye following experiments.

During a great frost I put water wch was already sufficiently cold into a cylindric vessell of seven or eight inches height and six inches wide, fill it wch within two inches of ye top, and I attentively considered ye whole progress of its freezing. It began presently to congeal in ye upper surface of ye water into a long and pinnacle like blades leaving between intervals not frozen, which freeze also by little and little leaving a small space towards ye middle wch was not as yet frozen, when ye rest of ye surface was frozen two inches thick. I observed in ye bottom and even against ye sides of ye vessel small bubles of aire which soon drown themselves in ye ice which beginning to thaw, some would elevate themselves and others remaining engaged in ye water, whence I suppose that ye small bubles coming to possess much more place in ye water than when their matter was as it were dissolved might drive a little water up to ye hole which was above after ye same manner, as a cask full of new wine drives out a little at ye bung hole, when ye wine begins to ferment; and that little water which goes out through ye hole spreads it selfe upon what is next it

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Part I

and that being allready frozen, it freezeth also, and begins to form an elevation of ice, and ye hole remaining always open by reason of ye water wch passeth successively being thrust by ye new bubles of aire which form themselves in ye ice it continueth to encrease by little and little towards ye sides and bottom of ye vessell; I observed that ye upper superface of ye water was already frozen more than an inch thick towards ye brim of ye vessell, and more than an inch and a half round about, and nigh to ye small hole below that ye water which was as in a small channel was frozen: but at last it freezeth, and then ye middle of ye water not being as yet frozen, and ye water pushed by ye new bubles, which continually form themselves during two or three hours, not finding an issue through ye small hole ye ice suddenly breaks towards ye top by ye force of ye inclosed aire. I made a second experiment, in which after ye ice was about two inches thick, I heated ye brim of ye vessell to melt ye exterior part of ye ice, and that means took it whole out of ye vessell without turning upside down ye water which was as yet in ye middle of ye ice. I put that ice in ye aire to let it freeze ye rest of ye water, and three or four hours after it broke and I found in ye middle an empty place of an inch an half diameter, from whence went out ye rest of ye water which was not yet frozen and wch filled up that space. I made a third experiment; in which after I had in ye same manner taken ye ice whole out of ye vessell, I pierced ye place of ye small hole which was frozen with a great pin, and where ice was higher by an inch than ye rest, by reason of ye water wch had forced near ye small hole and had there frozen: after ye pin was withdrawn there followed it a small spout of water, and ye water froze again in ye hole. I continued to pierce ye same place from time to time till ye water was all frozen; I then exposed that ice to a cold aire during two nights without breaking; wch manifested unto me that ye breaking of ye ice in ye former experiments proceeded from ye force of ye spring of ye bubles of aire ye middle of that ice was mixed with much more of aire than of ice, and it had much and it had much fewer bubles in proportion towards ye exterior part of ye ice. if you boil ye water to draw out ye aerine matter before you expose it to freeze, it will freeze to two or three inches thick yet will not have any visable bubles and will be perfectly transparent and proper to burn with by ye sun like convex burning glasses: this is ye manner of rendering ice convex. have a small vessel hollow like a hemisphere or a half a foot diameter, put in it a piece of that transparent ice, and put it upon a small fire to melt ye exterior parts, pour out ye water by inclination as soon as ye exterior parts of ye ice are melted, turn ye other side and melt it till it has at last a convex figure ye two sides well polished and uniforme: then if ye sun shines it will have very much ye same effect in burning paper gunpowder as a convex glass. there are some that believe that boiled water freezeth sooner than other but having put equally of both into two equall glasses and having made them equally cold before I exposed them to freeze, I could never observe that they froze at all one before another.

If you thrust a stick into those places of moors where ye water is stagnant, and a heap of dust thrown up wherein ye aire is seperated as it passeth over it it will strike against ye mud that stoppeth it, whether that aire forms it self by little and little from ye aerine matter wch is found in ye water descending through ye small channels of ye bottom of its bed, elevates ye aire with it three kinds. besides ye aerine matter wch is found in ye water, there is another matter found wch may be called fulminating, such I observed by many experiments. Like this wch I have related. put into a small copper or tin vessel a large drop of water and above it oyl to ye hight of an inch, put a lighted candle below ye vessell at ye place where ye drop of water is; you may see bubles of aire seperate themselves for a certain time, and then no more or very few will seperate; but when ye oyl is hot, ye drop of water will fulminate and lift ye oyl up on high; and break ye drop of water into two or three parts. this effect may proceed from some new salt or some other unknown matter dissolved in ye water wch attaining a certain degree of heat immediately dilates it self like to aurum fulminans.

The Analogy there is between oyl and water is that oyl that grows compact and is thickened by a great frost, but not so strongly as water, for it rises with a very moderate heat, and a great heat raiseth it into fumes and exhalations much of ye same consistence

of ye vapours that seperate from water and at last these fumes, being of exceeding subtile parts, do by a very great change into flames.

Tin, mercury, and water in wch there plenty of salt dissolvd, do not freeze or grow hard by cold any more than spirit of nitre spirit of vitriol or other aqua fortes, but these remains always liquid and running: these aqua fortes are also elevated into vapours by heat.

= mercury, water, oyl, wine, spirit of wine and other liquors are dilated by heat, and con-
= densed by a moderate cold, yet without ye appearance of any any air that should mix with ither
= any bubles seperate from it. put oyl into a long and narrow necked bottle, and warm it moder-
ately; it will by little and little rise into ye neck and when it is cold will descend down into ye body without ye appearance of ye coming in or going out of any air; and if ye same bottle being full of moderately hot oyl is drawn and stopt with ones finger, and you then dip ye top in cold water as low as halt ye neck, ye oyl cooling quit ye neck wch it occupied, and ye water will mount thither; but if you moderately heat ye bottle, ye oyl will descend and chase away ye water without ye appearance of ye forming of any bubles of air, this effect is very sensible in spirit of wine. where with they fill glass thermometers called hermetically; for when it is very cold, ye spirit of wine will descend down to ye ball and of wine ~~will descend down~~ and in a great heat will mount to ye top of ye pipe also it be more than two feet high, I have seen these monsters full of mercury instead of spirit of wine, wch would produce much ye same effects.

mercury is not elevated into vapours but by a great heat. I kept during two years a small bottle which had in it a pound of mercury, in a closet where ye sun might shine during ye summer, and at ye end of that time I found sensibly ye same weight; but if you put in a sufficient great fire, it will all elevate into visible vapours, which being received in an alembic, return into running and liquid mercury as before ye evaporation.

There is observable in water a certain kind of viscousness wch causing ye parts one to another and to other bodys as to wood and clean glass so that a drop of water sufficiently thick remains hanging to ye glass or wood without falling.

This although one cannot well say in what this viscousness consist, it is certain that these effects are constant; for two drops of water seperated, joyn together as soon as they come a little to touch, and make but one drop: ye same thing happens to two drops of mercury, to two drops of oyl placed nearby on water when they approach one another; one may see ye same that ye small bubles of air wch are in ye bottom of a dish full of water when it hath been upon ye fire, will join to that wch is next it with a pin or other instrument you push one against another. I once saw a small piece of mercury about an inch thick went along a table of pol-
= ished stone, it met with a small hole in ye table where some of ye mercury went in, and ye
rest continuing to run was just seperating from that little wch was in ye hole that which should joyn thirn not being above two lines large; but that viscousness which tied together ye parts of ye stronger mercury and that wch was past by made it again approach that part wch was in ye hole, and all ye Mercury stayd about and round about. In some measure to explain this viscosity, one may say that some of these matters are in perpetuall motion and that those of such a kind have certain figures proper to tie and hook one with another, and that they as soon as they touch one another are by reason of their motion so embarrassed and hooked. one may guess at another cause to wit, that ye air having a elastick power may reduce fluid bo-
= dys into ye least space that they occupy wch is a physicall figure, but it might as well reduce into a globe a drop of water and a drops of mercury alone, and that same cause will not act in a wind pump when one hath pumped ye air wch is under ye recipient, for that which remains hath not any considerable elasticity and never ye less ye drops of air and Mercury joyn toge-
= ther and become round in that extremity wanting air after ye same manner in common air. on these doubts you may be content. to know by experience that fluid bodys are natura-
= lly disposed to joyn together as they touch, and you may if you please call this a motion

of union. there are certain bodys to wch water will not at all or very difficultly stick as to grease, ye leave of coleworts not handled, ye feathers of swans and ducks, and it will there put it self into small balls, or if it is there in a great quantity it will be found in ye bnd of ye rest remaining level. Mercury fastens either to glass, wood or stone and hence they have given it the name of quick silver, for when it is in a small quantity it runs upon those mat- ter by ye weight till it meets with a small hole wch retains it, but it easily fastens to tin, gold, and some other metalls. and also is imbibed in ye interval of ye parts and composeth but one body with them, and this is what ye chimists call Amalgamate.

The Second Discours
Of
the origine of fountains

The fumeous vapours wch rise out of seas, rivers, and moist earths being arrived to ye middle region of ye air, and leaving there ye armed clouds grow colde, and are not able to mount higher, because they meet with an air less condensed then that wch is nearest ye earth, and that also being less heavy they cannot sustaine themselves. these vapours being agitated by winds meet one another and thick together, and of many small drops they make sufficiently thick ones wch beginning to weigh more than ye air wch is below and descending by little and little they meet with other small drops from whence they grow bigger successively, and by that means ye bnd come down drops of rain. those wch come from very high clouds are ye more great because they have more space to gather it in; and hee who is deceived when he holds ye contrary: & upon that he replies if that if one cast a pail of water out at a high window it will divide it self into more small drops than if one had not cast it from so high a place; but this comparison is deceitfull, for it is very true that a drop of water as of an inch thick falling violently doth easily separate ye flock of ye air into two or three parts, especially if there is a great wind, and so ye greatest drops are not above three lines large and when two or three of these drops joyn together they presently after separate but they cannot arrive to ye thickness of three lines diameter but by joyning many of them together; and one sees sometimes when ye mist thicken very small drops of rain wch cannot be discerned but when there is some black object behind them.

Since that ye rain is in its beginning very small, it is evident that to grow great it must fall from a great height; and it is for that reason that ye rains in ye winter are ordinarily smaller than those of clouds are then but low. I have observed that ye air being covered with thick clouds and it raining thick with great drops, at ye foot of a very high mountain, ye drops were smaller as I went up ye mountain and when I was almost at ye top ye rain was very small; I was then in a mist wch appeared to me to be a cloud when I was at ye foot of ye mountain.

One only cloud pushed towards by ye violence of winds may rain successively through a large space then 50 leagues, this is very remarkable sometimes by ye havock wch hail makes that is formed out of one only cloud.

The rain being fallen penetrates into ye earth by ye small channel wch it there finds, whence it is that when we dig a small depth into ye earth we ordinarily meet with the ye small channels, whereby ye water being assembled at ye bottom of ye pit when digged make well water, but ye rain water wch falls upon hills and mountains having pene- trated ye surface of ye earth, especially when it is light and mixed with flint stones and ye rocks of them, it meets oftentimes with slippy earth, or continued rocks along wch it runs not being able to penetrate them till being at ye foot of ye mountain or a considerable distance from ye top, it comes into ye air and forms fountains, this natural effect is easy to be proved, how first rain water falls all ye year in a sufficient quantity to maintain fountains and rivers, as you may see by ye following calculation, secondly you may observe that fountains do always increase or diminish as it rains or doth not rain, and if there hath passed two or three months together without any considerable raine, they

diminish almost halt, and it that drayns continueth two or three monthes Longer, ye great= = part dryes up and ye other diminish $\frac{2}{3}$ or $\frac{3}{4}$ from whence one may conclude that if it should ceese to rain for a whole year, there would remain but very few fountains, whereof ye most part would be very small, or that they would all wholly ceese.

The great rivers as ye Seine diminish oftentimes at ye end of Summer more than $\frac{5}{6}$ of their greatness, when ye drought continued not three together: and if there is some fountains wch diminish not above $\frac{1}{2}$ or $\frac{1}{3}$ it proceeds from hence they have great reservatories wch have been digged in ye rocks hence it is that they do not by continual drains increase so much as others. Some Philosphers do bring another cause for ye origin of fountains, to wit that there is elevated vapours from ye bottom of ye earth wch meeting with rocks at ye top of ye mountain in ye form of vaults, are reduced into water as in ye head of an alembic, and that water afterwards runs to ye foot on in ye hanging places of ye mountain: by this hypothesis can difficultly be rightfied, for if A B C is a vault in ye mountain D E F it is manifest that if ye vapours should be reduced into water in ye hollow of ye surface A B C; it should fall perpendicular towards H G I and not towards L or M and by consequence would never make any fountain; moreover it is denied that there may be such plenty of such vapours in ye mountains and none knows how to prove it, but if it be said that there is such in ye earth at ye side and below A B C it will be answered that ye vapours fly out from ye side towards A and C and that thence will return but very little water, and because there is almost always found a slipping earth where there is fountains, it seems probable that they pierce the water alembick cannot pass through, and by consequence that fountains that fountains cannot arise from this cause.

Some authors report that fountains have ceased to run after ye opening of great subterranean cavities, whence issued out a great quantity of vapours wch might be resolved into waters in these caverns; to this it may be answered that these histories are to be suspected, it cannot however be denied that there might have been such disposings in ye top of a mountain, principally in such are covered with snow, that ye vapours which might be condensed by ye meeting with a bed of stone as in an alembic, might form some small stream of water wch might run out at ye side; but this is very hard to meet with, and one cannot from thence draw a consequence for other fountains.

It may be objected ye Summer rains although very large, do not enter into ye earth above a foot as may be observed in gravelly and plowed grounds: I yet doubt ye experiment, but I maintain that in untilled earth and in wood there are many small channels wch are near enough to ye surface, in wch ye rain waters enters and that these channels are continued to a very great depth, as may be seen in deep digged wells, and that when it in rains two or three days together, at ye top of ye plowed grounds is entirely wet and ye rest of ye water passeth into ye small channels wch are below, and wch have not been broken by ye plowing.

There may be seen in ye caves of ye observatoire royal at Paris many drops of water which fall from ye top of natural stone vaults wch are there, but it is easy to observe that these do not proceed from vapours, for they are always seen to run two or three

cracks or some small holes in ye rock, ye other places remaining dry or but very little moist, and this happens after great rains: there also a place where there is a great vault, where always distills many drops of water, but these proceed from a mass of water wch is directly above.

There is of these gutters in many places where ye top is in ye form of a vault, and there is not above twenty or thirty feet of earth about, ~~twenty or thirty feet of~~ where it may be observed small gutters of water wch are there made pass thro' ye small chincks between ye beds of stone and that they proceed from rains because they do not appear but after great rains, and they do not continue above a fortnight or three weeks after it hath ceased to rain, and it may be easily judged that ye other drying up of fountains are of ye like sort.

The summer of ye year 1681 in France was very dry, wch made ye wells and fountains to be in many places almost dry, and altho' it was sufficiently cold at ye end of october and beginning of november, ye waters continued to diminish which would not have happened if ye water had been made by vapours elevated from gutter-vaulted places and condensed by ye cold of ye surface of ye earth. there is a hole in ye caves of ye observation which had always had water from ye year 1668 till 1681 but ye dryness of that year wholly dryed it up and there was not as yet a drop of water in february 1682. altho there had been much rain during many days at ye beginning was sufficiently rainy, ye water did not return at September, now during the whole years.

If there is cast upon ground that is firm and difficult to be penetrated by water a great quantity of stones, sand and matter mixed with earth to about ye hight often or twelve feet there will be a small fountain ye lowest place wch will always run, if ye ground be an acre or two big.

I saw this effect in a place where had been heaped up matter to ye hight of about three feet its superficial content might be somewhat less than 500 toises, it came to pass that ye rain wa- ter wch fell upon this place and upon ye tiles of ye neighbouring houses was retained by this matter and could not pass but by little and little transversely and being not able to penetrate ye pavement and firm ground wch was under it, it would at last turn towards a low place where it might make a continual small stream of water:

toise is foot

Sometimes ye earth in mountains is so disposed that ye water wch enters there can get out to ye air and run between two banckes or between ye earth and ye rocks and then it cannot be discovered but by making trenches at ye same side sufficiently deep, and it happens sometimes that by that means there is gathered together a reasonable quantity of water, as it is practised in many places.

There is some fountains wch come from ye middle of mountains, and they are made when ye rain water having found a passage thro ye sandy earths and cracks of ye rocks to two thirds or ¾ of ye inward parts of ye mountain there finds a continued bottom of smooth hard earth or some con- tinued beds of rocks, where ye water stops and is heaped up to a considerable hight, wch pushing on all sides by its weight, makes at last some passages towards ye base of ye mountain thro some cracks in ye rocks. these fountains during dry weather last longer than others and may be changed with divers salts and other matters wch they there may dissolve.

There may be seen sometimes fountains almost at ye top of mountains and some main- tain that some are at ye very top; I have observed such a fountain in a mountain two leagues from Dijon, it has plenty of water: and one is very near it seems to be about 40 feet high from ye earth to ye top where ye ridge is very stiff; but if you look at ye mountain saw off it is seen to extend it self with a sufficiently tenable ridge more than 100 toises Long and 200 broad. now if that space there falls sufficient rain to maintain that fountain as shall be hereafter proved.

Happen There are lakes at ye top of some mountains wch arise from small rivulets &c may because that ye earth round about ye lake is more elevated than ye Level of ye water and of a great extent &c: Cassini told me there is in Italy a sufficiently great Lake in ye top of a mountain where there is an elevation of ye earth round about it above half a League long wch would be sometimes covered with snow ye drains of wch with that of rain water may easily feed ye Lake, wch ought to have at ye bottom a firm earth or continued rocks it is there ordinarily very cold whether it is that ye water doth not exhale considerably.

There is a fountain at mont-valerien about two leagues from paris: ye Land that produceth it is about 100 toises Long and 50 wide: it is near to a house about a third of ye ~~side~~ hight mountain. there is also many other places of ye same sort in wch there is some water and where there is made small running fountains by digging ye earth seven or eight

foot deep; tow if after ye water is found; ye passage is continued horizontaly inclining towards ye base till that you have gained ye top of ye earth, you will have a small fountain wch never ceasingly dureth up. there is at ye other side of ye same mountain very neer ye base a neat fountain wch doth not dry up. there are tow at Mont-Mantre; ye hight of ye mountain from ye bottom to ye top is about 500 feet; ye ground wch produceth ye fountain, is not above 300 toises long and 100 wide it gives but very little water and that after great rains, ye others give not a fourth part of ye great one, and run not but after great rain.

The town of Langres is situated at ye extremity of a very high eminence, wch continues in ye same hight to ye length of a league, with a moderate largeness; there is near it another mountain almost of ye same hight and length, and more than a quarter of a league large between these two mountains there is a great valley where runs a sufficiently great rivulet or small river wch proceeds from many fountains wch are not far distant from ye top of these mountains; and it is easily to judge that these are produced by ye rain water wch falls upon ye plains wch are at ye top and wch are very spacious; they thence come most from wch is Langres

All ye other fountains are near like to that and should have considerable heights from ye top of their springs out. there is a plain 6 leagues from Paris, between ye valley of Perai= =eux and that of Montcouffi wch is more than two leagues long and one broad, where is seen meers in some places wch are within 5 or 6 feet of ye top of ye places, but ye earth there is very hard to ye depth of 100 or 3 feet particularly near ye castle of Beauregard where there is, there are found such meers and ye earth is also impenetrable by ye water, that there may be made a conduit of water, if one is content to digg a small ditch 2 or 3 feet deep and to fill it with stones without puting any cement in ye bottom.

It may be objected that there doth not fall enough water in a whole year to furnish ye great rivers wch discharge themselves into ye sea.

To resolve this difficulty I shall make use of an experiment wch was at my request made seven or eight years ago at Dijon by a very able and very exact person in his experiments. he had put towards ye top of his house a square vessel of about 2 foot diameter at a square vessel ye bottom of wch there fell into a cylindric vessel, where it was easy at all times to measure at all times how much it rained; for when ye water was in ye cylindric vessel it exhaled but very little in 5 or 6 days, ye two-foot vessel was sustained by an iron by 6 feet beyond ye window where it was placed and kept, so that it might receive no rain water but but what fell immediately into ye wideness of its overture and that there might enter more but what ought to fall according to ye proportion of its superior surface. The result of these experiments was that there would ordinarily fall in a year rain water to ye hight of about 17 inches. ye author of ye book intituled of ye origine of fountains was wont to make ye like experiment during three years, and of late with another there fell of rain water in a year to ye height of 19 inches 2 lines and $\frac{1}{3}$

If I take ye mean in these observations and suppose that there fall of rain water only to ye hight of 15 inches, upon this ground a toise will receive in a year 45 cubic feet of water and supposing that a league contains in length 2300 toises a square league might contain 5290000 superficial toises, wch multiplyed by 45 give 238050000 cubic feet.

The sources wch are farthest distant from ye Seine are near 60 leagues from Paris, to wit those of ye river of Armançon and ye other rivers wch enter into ye rivers yonne and ye Seine reckoning from ye sources next ye Loire near to Chorite and those wch enter into ye maine from those wch are next to ye Meuse beyond Bar-Leduc. ye greatest distance of these sources one from ye other is near 60 leagues. If ye river be cut by a perpendicular line that passeth to 5 or 6 leagues of Paris, from ye east of Corbeil these sources are found towards ye extremities of that line, wch are distant ye one from ye other about 45 leagues. I suppose that ye whole country is 60 leagues long, and with 50 leagues wide it makes 3000 superficial leagues ye product of wch by 23880000 is 71415 0000000 whence is seen that ye ground with furnisheth water tow ye river Seine at Paris, may receive in a year 71415 0000000 cubic feet of rain water.

The Seine above Pont Rouge when it toucheth ye two keys without covering but ye very extremity of ye Earth is from side to another 400 feet wide and five fect mean depth it is then in its mean greatness, ye swiftness at ye top of ye water is such that it makes about 150 feet in one minute, it makes then 250 when ye waters are in their greatest hight: for a stick wch is carried in ye midle of ye current, goeth as swift as a man wch marches a great pace, it may make 15000 feet in an hour, and by consequence 250 in a minute, that is about four feet in one second; but because that ye bottom of ye water doth not run so swift as ye midle nor ye middle as ye superficies or surface as shall be here after proved; one may take 100 feet in a minute for ye mean swiftness.

The product of 400 feet Longe by 5 feet ye mean depth; for it is 8 or 10 feet in some places and 6 or 3, or 2 in others, and ye product of 2000 by 100 feet, is 200000 cubic feet, and by consequence there passeth by a part of ye shore of ye river Seine above pont Rouge 200000 cubic in a minute and 12000000 in an hour, and in 24 hours runs 288000000, and in a year 105120000000, wch is not ye sixth part of ye water wch fally in a year in rain and snow; to wit 71415 0000000 cubic feet. hence it is manifest that althó ye third part of ye rain water should elevate it self in conti= =nently into vapours after it is fallen and that half of ye rest should remain in ye superficiall parts of ye Earth to keep them moist as may be ordinarily seen, and in and in subterranean caves at ye bottom of great Plains, and that it was but ye rest that might run thro small conduits to make ye fountains at ye bottom of ye sides of mountains, and rivers such as we see. if we take in ye calculation above 18 inches instead of 71415 0000000, 8567 8000000 cubic feet which would give 8 times more water than ye Seine there runneth.

To calculate ye water of ye great fountain of mont-Mature, we must multiply 300 toises Long by 100 wide ye product is 30000 toises wch at 54 cubic feet ye toise will give 1620000 cubic feet, near in a year. Now ye Earth of that mountain is sandy to two or three feet deep, and ye bottom is a slippy Earth; one part of ye waters of rains runs presently to ye base of ye mountain, one part of ye rest remains in ye sand near ye surface, ye rest runs between ye sand and ye slippy Earth, and if it is supposed if there doth not issue out above a fourth part of ye whole, wch is 5670000 in a year, or 15534 in a day, wch makes 6472 pints in an hour and 107 in a minute, ye fourth part will be about 26 pints in a minute wch ought to give this fountain, and is by wch it gives very near, when it is more than mean.

Discourse III

The origine and causes of winds

The origine of winds is much more difficult to discover than that of fountains because that Seine fountain having ye beginning of its production, and ye issue of its source in one mountain only, one man alone may observe all its most considerable circumstances, but ye same wind being extended very often thro ye space of more than 100 Leagues, there is a necessity for many observations at ye same time, to know where it begins and where it ends and what space it possesseth in widenes.

I have attempted many times to have had correspondents for these observations within ye extent of seven or eight hundred leagues in many places of Europe at ye same time as from Paris to Rouen and towards ye extremity of Italy and Spain and from London to Constantinople, from 100 to 100 Leagues. but althó many curious persons to whom I had spoke or writ might have promised me, and that on my part I have exactly made mine at Paris and elsewhere, I have had but little from my correspondents, of wch I shall not speak.

Aristotle and some other Philosophers have believed ye winds proceed from exhala= =tions or fumes elevated from ye Earth, when they are rarified after having mounted per= =pendicularly to ye middle region of ye air. this opinion is very improbable, for these ex= =halations elevated very gently, and consequently their rarefaction can give but a very

feeble motion to ye air, and can produce but a very moderate wind wch should not be ordina=
=rily generated but in ye middle region of ye air, and not descend to ye surface of ye earth.
It is true that if there is elevated in some particular place an extraordinary quantity of exha=
=lations and vapours, that might posses sufficient place in ye air to push back one part to
ye circumference, but that motion of ye air would alone be too feeble to produce any consid=
=erable wind, and wch might might have a force equall to that of ye most part of winds, It
would follow also if that opinion be true, that there would happen no winds in ye ocean sea
towards ye coasts of France and that of Spain, seeing that there is none or but very exhalati=
=ons elevated from sea water but only aqueous vapeurs, and nevertheless there is often times
very violent west winds

Mr Descartes who would render a reason of all things, did believe y clouds wch were
just a falling vesolving into rain, might produce winds by falling from on high one upon
another but he did not consider that there is no cloud so thick wch hath not much air
in ye intervalls of ye vapours wch compose it, and that for ye same reason ye air wch is
between two clouds may pass easily through as soon as they approach one another, as
when they fall down towards ye earth, Add to that ye superiour clouds descend so gently
upon ye inferiours, that it is impossible that they do give so great a swiftness to ye air
that is between them, and there can never arrise a motion in ye air in most valley coss
wch can be caused thro any considerable space. ye reason wch that author brings to
prove that ye clouds highly elevated may produce tempest, to wit that ye higher
heavy bodies fall ye more violent their fall is a meere sophisme: for that happens not but to a
body very heavy as stone and mettals, but in regard to ye clouds wch begin to descend when
they are about being resolved into small drops of rain, ye greatest force wch they can acquire
in falling, is to make 5 or 6 feet in ye space of a second, and these small drops may
acquire that force in coming only from 50 feet high. ye same author as also endeavoured
to explain ye winds by ye unequall dilatations of vapeurs and hath maintained that ye va=
=pours dilating themselves 1000 times more in proportion than ye air, they ought to be ye
causes of winds, giving for example ye wind of ye Eolipiles; but all his reasons are built
upon false suppositions: for it is not true that ye water being extreamly heated produceth
nothing but vapeurs, for it produceth also much air and other matters yt much varified,
as hath been above explained; and it is that wch makes ye wind in ye Eolipiles and of aque=
=ous vapours wch these varified matters have carried out with them. for these vapours wch
are nothing else but small parcells of water wch ye heat hath seperated from ye rest of
ye water are not changed into air, and do not posses more space for being more warm'ed,
since that is not to speak properly a dilation but a seperation of these small parcells;
after ye same manner as when there is thrown into ye air a handfull of ashes or ye dust
in a chamber, ye small parcells of ye ashes being dispersed, do not posses more place in
ye chamber than when they were in ye hand, and do not push ye air downwards to make
themselves room; and if it were true that ye vapours wch compose a cloud did beget winds,
y clouds should remain immoveable, and should push ye winds on all sides round it, which
is contrary to observation. for it is seen by experience that ye winds push and carry ye
clouds. I observed one day being on ye top of ye platform of ye observatorie, that there came
a thick cloud from y west, whence was seen to fall a very thick rain; that rain might
fall 300 paces from ye observatory; but there was not yet perceived any considerable wind
upon ye platform; I descend with those that were with me to avoid ye storm, wch lasted
seven or eight minutes, and when that was ended, I saw ye cloud that was passed, and that
was a great way before; but it did not make much wind considerable upon y platform
wch manifested to me that it was ye wind wch had caused that rain, and that ye cloud
from whence ye rain fell did not produce ye wind wch pushed it forward, this I explain
in ye following manner,

when there is excited by some cause whatever it is a sufficiently great
wind in a part of ye air near ye earth, it chaseth before it ye vapours wch it meets and
heaps them up one against another in a little time; for it blows so swift as to make
20 or 25 feet in a second it may pass 6 or 7 leagues in an hour one from a cloud of more
than a league long and broad, as was that whereof I spoke, and at last when these

small pawcells of water wch compose ye vapours are much purified by ye winds they are formed into drops of rain as is explained before when it follows that it is ye wind wch makes ye clouds and rain, and that ye clouds do not make ye wind.

Here is some conjectures wch appears to me very probable about ye true causes of winds, such I have found upon many observations wch I have made or caused to be made, or wch I have drawn from many relations of sea voyages.

I suppose that any swiftness wch can be given to a space of air of ye thickness of a cloud, cannot continue a sensible motion every ye west of ye unmoved air but to a very small part of a League or more, this is easily to prove by experience in pushing ye wind in a pair of bellows from one end of a chamber to ye other.

I suppose also that there is elevated more vapours of water from sea than from Land and more nitrous and sulphurous fumes from uncovered earth than from that wch are under water.

This being supposed I say that there is three principall causes of winds and some other less principall causes particular and less principall. ye three principal and generall are.

1 The motion of ye earth from west to east, or that hypothesis is not admitted by of ye heaven from east to west.

2 The changes of ye rarefaction of ye air by ye heat of ye sun and its condensation when ye sun, and of its condensation when ye sun hath ceased to heat it.

3 The changes of ye elevation of ye moon towards its Apogaum and of its descent towards its Perigaum.

The most considerable particular causes are 1 some extraordinary elevations of exhalations and vapours from ye earth in certain places.

2 The fall of great rains, or of some great and thick hail.

3 The eruptions of a quantity of sulphurious and nitrous exhalations in earthquakes.

4 The sudden melting of snow in ye tops of mountains. These particular causes fortify ye principall or diminish and hinder its effects according to ye diversity of time and place by many combinations. The eruptions of exhalations may be very irregular in point of time and in their quantity and force, ye like irregularity may be seen in y time of earthquakes and in ye variation of ye magnetic needle, and one may deduce both to some great changes wch are from time to time in ye bowels of ye earth. It may be seen also that running mountains make not their first eruptions in ye intervals of time limited and prescribed.

By these causes both generall and particular, may be explicated all winds, as shall be seen in ye sequel.

It is manifest that if ye earth turn about its center from west to east ye surface goeth much more swift under ye Equinoctial Line, that at 30 or 40 degrees of latitude on one side or other and that surface drawes along with it ye air wch is near it, but not so swiftly whence ought to be discovered a motion of ye air from east to west to those that are under ye Equator, as far as to ye Latitude or more than 20 degrees on each side, since that motion being more swift than that of ye air wch follows it they ought to perceive ye shock of ye air as they successively encounter, and from thence may proceed ye winds called Alizes wch almost always reign between ye 2 Tropicks; but they have this difference, that when ye sun is at ye tropic of cancer, it makes ordinarily ye wind noth-east or east-noth east, and when it is towards ye tropic of Capricorn, that wind is ordinarily south-east, wch may be easily explained by ye second cause; to wit, ye rarefaction of ye air excited by ye heat of ye sun: for when it is in ye signs capricorn and sagittary, it much heats ye air and ye earths wch are under it, whence it happens that air being extreamly dilated, and that such is in ye opposite signs being condensed at ye same time by ye cold of ye winter wch then reigns there, there necessarily follows a motion of ye air from ye south towards ye north, wch joyning with that motion wch goes from east to west, it ought to make a wind composed of the two, to wit, a south east, or east south east, and on ye contrary when ye sun is in ye tropic of cancer, it ought to make a motion of ye air from ye north towards ye other pole, wch joyning to ye same motion of ye air from

East to ye West, makes a north, or East = north = East wind.

Some Pilots relate that ye West winds reign ordinarily in ye ocean Sea from ye 27 degree to 40: I explain these winds in ye following manner taking 33 degrees Latitude for an example.

The aire wch is between ye two tropics goeth a little less swiftly towards ye East than ye earth wch is under it since there is felt but a moderate wind, wch makes not ordinarily above 8 or 10 feet in a second whereas ye surface of ye earth wch is under ye Equator, makes in ye same time 1423 feet: but ye surface of ye earth at 33 degrees of Latitude makes but 1195 feet and by consequence if ye aire wch is under ye Equator, it would go swifter than that surface about 228 feet in a second. now if ye aire of 33 degrees had not its motion but from ye wch is under it that draws it there should be there felt a East wind whose swiftness would be about 8 or 10 feet in a second; but because ye aire wch is from ye Equator to ye 10 degrees draws that wch is at ye side always deminished to ye 33 degrees it may happen that diminution is there reduced to 2 feet in a second, so that being joyned to ye diminution of 10 feet in a second in ye contrary part wch would have been if there had been no other cause ye aire should be there pushed to make 10 feet in a second more than ye surface of ye earth towards ye East, and that there will be felt a west wind as great as ye winds called Alizes which are between ye Tropics. Add to this that ye winds called Alizes in coasting ye coasts of America bending like an half moon from Cayenne to ye Gulph of Mexico, may be helped against their high mountains, and help to produce these West winds, and augment their swiftness, and these winds should be perpetuall if they were not hindred by some one or more of ye other causes whereof is spoken above.

There is many places between ye two tropics where there is extraordinary winds wch come from ye earth towards ye Sea about ye beginning of night, and from ye Sea to ye shore when ye Sun is almost at ye meridian; these winds may be explained in ye following manner.

Let us suppose a great Ile wch may be at ye Latitude of 15 or 20 degrees, where ye Alizes may be felt, ye Sun heating ye ground of that Ile from noon till to 4 or 5 hours of night, and at ye same time ye Sea wch is near it for that cause makes not a sensible motion of ye aire; but immediatly after ye Sun is set, ye aire of ye Sea is much condensed loosing its heat, and ye earth of ye Ile preserving their heat a long time, ye aire wch is above is not condensed but by little and little, and much less at ye beginning than that of ye Sea, whence there ought to happen that there should be a wind by ye motion of ye aire of ye Ile wch runs to fill up ye place of that wch is much condensed above ye neighboring Sea. but as soon as ye Sun riseth ye earth of ye Ile being cooled by ye length of ye night, and ye aire being there much condensed, it ought to make a reflux of ye aire wch ought to come from ye Sea, sufficient to produce a small wind coming from ye Sea against ye coast.

The changes of ye winds or their flux and reflux are also remarked according to some relation a Long ye Mediterranean in certain seasons of ye year; for they assure us that there is a East wind in ye morning and a West wind at night. ye first may proceed from ye dilatation of ye aire wch is made towards ye countrys wch are East of that Sea; to wit, natolia Syria &c. where ye Sun is already much elevated, when it riseth in respect of ye Mediterranean and that dilatation may make East wind be perceived towards ye Ile of Platta and Sicily: but two or three hours after noon ye West wind ought to be perceived till low in ye night, because of ye dilatation of ye aire by ye heat of ye Sun, wch then strongly heats ye earths wch are beyond that Sea as Spain and Affrica, and ceaseth to heat those wch are towards ye East, whence there necessary follows a reflux of ye aire from ye West towards ye East in ye middle of ye Mediterranean.

In ye beginning of November there is caused in ye Ile of France, in Burgondy and in ye Champaigne South winds wch bring great rains; because that ye countrys towards ye North pole do no longer see ye Sun, and ye aire is there condensed by excessive cold whence it happens that ye Lands of Affric being then much heated, pushs thither their aire for many days together, and it is gathered there beyond an equi Libirium whereby it flows back and makes a north East wind gentle enough because of ye South wind wch carrys thither a warm aire wch coming to reflect gives fine weather and a little cold 3 or 4 days together, and a little it is this wch is called ye Summer of St Reny or of St martin.

It may easily be comprehended that when ye Sun shines perpendicular upon a great place of earth, ye aire wch is above is much heated and extended from all parts in ye circumference, and

that ye aire growing cold from all parts in ye circumference, by ye absence of ye sun, there ought to come a reflux of aire. this flux and reflux of aire may be seen also in Little. Mr Huygens told me one day that he had observed that his chamber being well shut, his Ba= =rometer such was of that sort wch depress their Liquor by ye greater weight of ye aire, and whereof ye changes of light are very sensible, was depressed and raised alternately many times in a quarter of an hour. I attribute ye cause to some wind wch was cooled in ye cha= =nney chimny, wch hovering there pressed ye aire, it had given a greater spring wch had made ye Liquor in ye Barometer to descend, and that condensed aire hovering afterwards by ye cessation of ye cause ye liberty to be extended, might repass thro ye chimny, and its spring being diminished ye Liquor of ye Barometer might remount; and because that ye motion acquired by ye aire wch remounted thro ye chimny might be more than to cause an Equilibrium, it might cause a new des= =cent of ye aire thro ye same passage, wch might again put ye condensation of ye aire in ye chamber beyond an Equilibrium and might make ye Liquor in ye Barometer to descend, and so on, di= =minishing by Little and Little till to an intire reduction to an Equilibrium.

I saw a Like effect in a furnace made of Lime, it was like to a small vaulted chamber where it had in ye middle a square window of a foot and a half wide, by wch ye wood might be cast in to maintain ye fire. it happened that fire being great, ye inclosed aire did extreamely dilate it self, and that it went out in great throng thro ye window with much swiftness, and ye fire being then diminished by ye effect of aire, ye heat of ye inclosed aire diminished, and becoming by consequence less rarified, it returned thither necessarily thro ye window in ye form of wind wch blowed ye fire and again kindled it, wch did anew dilate ye aire by an augmentation of heat and made it again go out thro ye window. this change made a kind of respiration like to that of animals; those wch did this work told me that something happened in all their Lime furnaces, and they made me observe that ye Little flyes and other animals, wch fly in ye night towards ye light of fire, being a foot or two from ye aire wch went out with great swiftness after it had been gone out. the time of this respiration was three or four times as long as that of ye respiration of animals

I have observed by many observations at Paris and in ye neighborhood, y winds made in 15 days almost an intire revolution blowing successively from all parts of ye Horizon, and that at new and full moon ye wind is almost always north and north=east. that is to say that if there is a north wind at ye new moon, it passeth to ye East in three or four days and afterwards to ye South, and then to ye west, and returns to ye north about ye full moon, whence it repasseth towards ye East, ye South, and ye west and returns at ye new moon to ye north or north=east. some of ye winds turn sometimes almost back as from ye west to South west and from north East to north, and then these winds last 7 or 8 days: but they almost never make a whole turn. it happens also sometimes that ye wind passeth from ye west to north= East and from ye East to South west without y intermediate winds being remarkable.

These revolutions of ye winds may be explained by y third principall cause in ye manner following.

It is very probable that ye moon rising at its Apogæum ought to draw much of ye aire after it, if it is supposed that it swims in ye aire, and that its diameter may be 5 or 600 Leagues, as Astronomers assert: for rising it ought to draw along ye aire wch is next it, that aire wch is under it, even to ye countrys under ye torrid zone; and for that reason ye aire wch is near ye poles on both sides ought to run ~~at its coming~~ thither to preserve ye Equilibrium of its spring, wch ought to produce ye north towards ye middle of ye north temperate zone, which joyned with ye East wind wch is produced by y first cause to wit by ye motion of ye Earth, composeth ye north East wch reigns at Paris ordinarily in ye new moon.

There ought to be made moreover a small north wind by ye great motion of ye aire drawn along by ye Earth, from ye Equinoctiall Line to ye 5 or 60 degree. I have experimented that turning swiftly a Lead ball of 2 inches diameter near to a pail of water what was at ye bottom of ye water would be elevated towards y ball with small heaps, and having hanged a ball of 8 inches diameter, and made it turn moderately swift, it made a great motion of ye aire at y sides, and another lesser at ye bottom and top towards ye pole of ye ball; I have

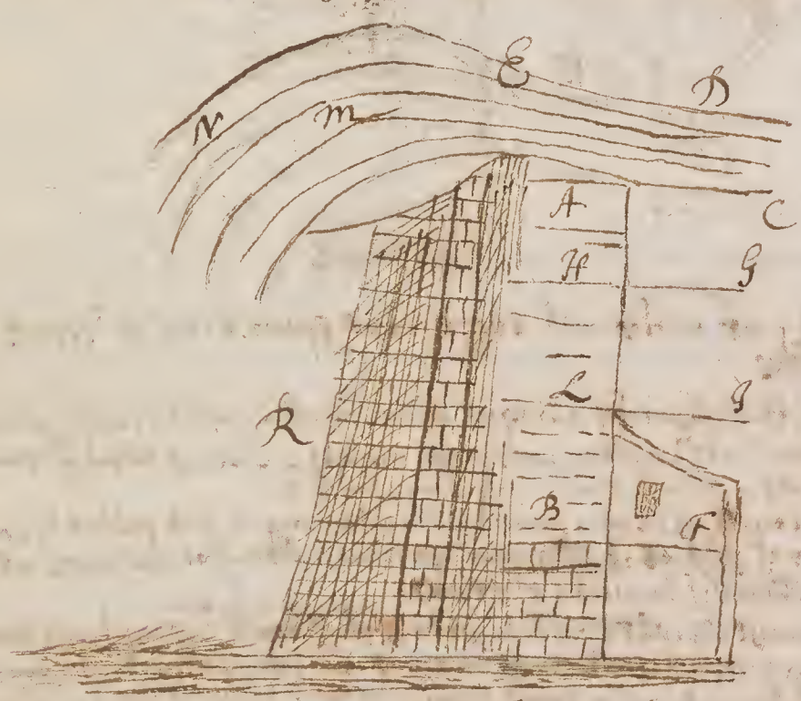
knew this by small down placed upon ye top of a small stick perpendicular, distant two or three feet from ye ball, wch would be moved as to be elevated towards it; but that wind was very small. whence it may be judged that ye air towards ye poles is moved against ye earth, and may be extended into 80 degrees, and then immediately at ye that cause is ceased and before that ye reflux of ye air elevated by ye moon returns towards ye Poles, ye motion of ye earth from west to East may make appear an East wind alone wch ordinarily lasts not above a day or two, for ye moon returning to its perigeum, pusheth reciprocally ye air towards ye poles and makes in ye beginning a South East wind by ye combination of ye motion of ye air towards ye poles, and of that wch comes from ye East. ye South afterwards reigns till that ye great motion of ye west winds wch reign to ye 40th degree as hath been said and wch may sometimes be extended to 8 or ten degrees beyond, advance a little towards ye northern climates and being mixed with ye South winds, make ye South west; and ye reflux of ye South being ceased, ye west wind alone may reign till that ye reflux of ye air, ye South wind had pushed towards ye north, joyns to that wch is drawn by ye following elevation of ye moon towards his apogeum, and by ye small motion whereof hath been spoken, makes ye north and north East as at ye new moon. this period and change of winds happens twice at every Lunar month. I have observed it for many years, and although these have suffered some irregularities by ye combination of particular causes; I have almost always found that ye north East reigned at ye new and full moons; and ye South and west at ye quarters: but one ought to observe, that as in rivers where ye flux of ye sea is vastly high, ye reflux begins to be made towards their mouths whilst ye flux yet mounts in many places a great way off, so ye north or ye north East blow not at once in ye same time that ye moon is at her apogeum, and that is not but after she is much approached ye earth. It is moreover easily to judge that when ye moon is towards ye tropic of capricorn in its greatest South Latitude ye air wch it then elevates or wch it thrusts back again takes a greater time to make its motion sensible towards ye north country, than when it is nearest ye north pole, and also that ye motion may be too feeble to extend unto ye 50 degree of north Latitude. I have observed sometimes at Paris that ye wind having been north East 7 or 8 days together and that ye South winds ought in their order to blow, ye north East yet reigned at ye bottom; but there was some clouds highly elevated wch were at ye same time driven by ye South, but very softly, this made me judge that towards ye 50 degree of Latitude ye South and South west might be there great enough to reign alone. It ought to happen also that ye inequal elevations of ye moon should make considerable in respect of ye winds, both as to their strength and to ye days where ye ought to reign. It is also necessary that there happen much irregularity in ye winds by ye mixture of particular causes whereof hath been spoken; but ye winds ought to be less irregular in ye places where there is few mountains, as in ye Ile of France and in champagne than in places full of mountains.

The motion of ye winds is never uniform, no more than ye current of rivers and it makes in ye same many waves and turnings wch are called whirle winds that have different swiftness. It is observed in great tempests that in ye space of ye 4th part of a League, where for ye most part ye trees are beaten down, there is intervals where there is none beaten, because that ye wind was there less violent. It is observed also that all ye winds blow by puffs and intervalls, this is known by ye sound of bells wch are heard diminished or augmented in small intervalls of time. Here is ye cause. Let us suppose that a great wind of a great compass incounters towards G with hedges and small eminences wch reflect it in some places, and make imparallell waves as A B C B it is evident that ye spring wch they cause by their incounter in B will make ye stream B D go swifter, and by wch is in ye direction G B will afterwards much more swiftly than ye storm in B. ye same ought to happen in all other places of wind.

It happens sometimes that when a great wind meets sideways another weaker, let it be opposite or not, it carries yᵉ wch is near it and makes it to turn verry swiftly and that turning of yᵉ air wch is called a whirlwind goth forward with yᵉ stronger wind, and carryes away all that wch it wraps up that hath not much weight; as dust, feathers and whole haycocks wch will sometimes fall above a quarter of a leagne distant. These whirlwinds also sometimes carry away a great quantity of water out of yᵉ sea, wch appears to those wch see it at a distance as a great pillar of water

There is seen an example of these winds wch blow out of yᵉ side both contrary in certain chimnys when there is made a great fire & doors remaining shut: for yᵉ rarefied air and yᵉ flame wch are elevated make one part of yᵉ air of yᵉ chamber to follow, and that wch remains being too much dilated by that means, it ought necessary to return from yᵉ top to yᵉ bottom thrô yᵉ chim= =ny, wch brings back a part of yᵉ smoak, and spreads it self thrô yᵉ chamber and ordinarily the smoak and yᵉ rarefied air mount on one side and yᵉ heavy descend by yᵉ other with one part of yᵉ smoak, this may be avoided by leaving yᵉ door or a window half open: for yᵉ air wch enters there follows yᵉ motion of yᵉ smoak thrô yᵉ chimny and sufficiently fills yᵉ chamber. and if there was only a hole of an inch diameter in yᵉ window or in yᵉ door to permitt yᵉ air from without to enter, there would be a sufficient wind to extinguish yᵉ candles that should be exposed to it.

When yᵉ wind meets with an obstacle a great wall it changeth its direction or is repressed beyond that obstacle, as may be seen in this figure in wch A B represents yᵉ wall and yᵉ Lines C A, C H, I L, F B, yᵉ direction of yᵉ wind being true. now it is evident that yᵉ



air is put into a spring between A and B, and that it cannot be extended towards yᵉ base, it ex= =tends it self from yᵉ side C A to b E, and yᵉ air wch is towards R having little motion that wch is in b M, is pushed thither by that wch is higher than M in N as is seen to happen to water beyond yᵉ piles of bridges where it is very rapid

From thence it follows that if on yᵉ side yᵉ wind comes there is a wall higher than a chimny, & smoak difficultly goth out, because that yᵉ wind turneth into a whirlwind after it hath passed yᵉ wall, and enters with force in yᵉ chimny. and althô yᵉ wall should be even with yᵉ chimny and a small distance from it would cause almost a like effect, as may be judged by yᵉ figure following, in wch A B maketh yᵉ direction of yᵉ wind B C is yᵉ wall oppo= =site to that direction, D E are two stacks of chimnys of yᵉ same hight with yᵉ wall. yᵉ wind

wch incountres ye wall is pushed back into F G, and enters not into ye chimny b, on ye contrary it draws along with it with violence ye smoak wch goeth out there: but ye superior wind to A B wch suppresses its violence incountring in G, makes it go into a whirle wind, and gives it a round motion G H E. and hinders ye smoak from going out. but if ye wind strikes obliquely ye wall wch is before ye chimnys ye smoak will mount out enough, for ye part of ye wind A B shall be reflected by ye side, and not be elevated or but very little, and by consequence shall make no considerable whirle wind wch depresseth ye smoak.

The diversity of winds wch reign at ye same time in divers places, proceeds from many causes

The first is, that ye winds always blow thrô a great circle, whence it is easily to judge that if ye same wind west or southwest makes a circuit thrô ye earth, it will appear very different in places a great distance one from another.

The second cause is that a great wind blowing in one place draws along with it pushing it a little to ye side, as is seen that is rivers, when ye midle runs very swift, it pusheth ye waves a little obliquely towards ye banks.

The third cause is, when in two places of ye earth distant one from another about 100 leagues, there is a great elevation of vapours and exhalations wch push ye air in circumference, yet it be at ye same time or some hours distant there is extended necessarily two contrary winds from one of ye places towards ye other, wch incounting flow back into opposite directions.

The fourth cause is ye incountring with high mountains, wch reflect ye winds and make them follow their directions. there is seen an example of this in ye Lake Geneva wch is extended between two ranks of mountains thrô ye space of 12 Lorge Leagues from Geneva to Lausan; for their almost never reigns but two winds wch succeed one ye other and blow according to ye direction of ye Lake, wch might also go one against ye other towards ye midle of ye Lake, if there should happen a wind at Geneva that is a little obligue to ye directions of ye mountains, and another at Lausan that is obligue on ye other side, as it E F G H are winds, A B C D ye mountains, for E F is reflected unto F G, and G H unto H L, these winds would be contrary towards M N.

The same thing happens at ye Port of Ambleteuse neau to Calais where ye South South west blows about three quarters of ye yeau, because that ye coste of England and that of France wch are opposite in that place have that direction, and at 10 leagues from thence it may make a wind at South East ou north.

I caused to be made some observations neau to Cherbourg, wch wch have made me know that there reigns but two opposite winds wch succeed one another alternatively, to wit north East and South west this happens from ye same cause the direction of some mountains.

Mr Cavin who hath made observations in ye Ile of Gorree neau cape verd, assured me that ye north west wind reigneth there oftentimes instead of ye East winds; this proceeds from hence that there is high mountains at a league distance from that Ile at ye north west side wch retreet towards it ye N.E.E. winds, East ou South East and make them perceived there as a north west when ye same N.E.E. winds are felt at ye same time at ten leagues beyond that Ile in ye sea. I have also learnt by many relations, that when vessells pass along ye coste of Genes where there is very high mountains, whereof some have between them long vallies, wch have their direction towards ye sea, there is felt a considerable wind wch comes from ye land toward ye vessell when they are over against some one of those vallies.

I have known also great diversity of winds in ye same time by ye observations made at Warsovie in Pologne by Mr Besnoyers, and at Aboudan in Ecosse by Mr Gregori, comparing them with this wch I have made at Paris at ye same time; for oftentimes ye winds there are different from those of Paris ye eight part of ye compass; ~~from those of Paris ye eight part~~ as if ye wind is South west at Paris it will be west at Aberdeen. ye winds are some times opposite at Paris and Warsovie, ye wind being one day South-west at Paris it was north East at Warsovie, these towns are situated almost west South west and East north East in respect one of another, whence it follows that these winds would almost directly incounter in some place of Allemagne neau that of Pologne ou that of France. I have also remarqued that opposition of winds in ye same place in travelling, by ye means of much snow wch was pushed in ye space of a league by a South East, and that in ye 3 or 4 following leagues, ye snow had been pushed by a north west, this I might easily know by ye stalks and great branches of trees wch had no snow but on that side ye wind had come

I have remarked ye like effect by ye observations made at ye same time at Paris, at Loches and at mont maujon in Genne, for a South South west having reigned three days in these three places wch are in ye direction neau to South South west ou north north East, there was made a north north East at Paris, a South South west yet reigned at Loches and at mont maujon: ye next day ye north north East was at Loches and at Paris, and ye

south south west at mont mavson: and ye third day ye north north east blowed in ye three twons: whence I knew manifestly that ye winds sometimes push back one ye other and that ye strongest carries away that wch is opposite to it. In ye same time correspondent observations, I have remarked their a violent west wind having reigned at Loches, there was at ye same time at Paris a west-south west entra west-north-east at mont mavson wch are = Lattes to ye second cause of ye diversity of winds.

I have observed a great diversity of winds at ye same time in ye same place when there was two or three stories of clouds, wch one may explain by supposing that ye higher clouds are ordinarily pushed by ye south winds and that ye lowest are pushed by ye north: for when that happens at ye same time, ye clouds of ye first or second storey ought to go contrary, and that hinders not but ye clouds much more elevated may be pushed by a west wind wch always reigns when not hindred by ye third principall cause other causes, or by a west wind produced by ye third principall cause, or by some other particular cause.

To observe well this diversity of ye motion of ye clouds, we must regard the top of some steeple, or some other fixed object that is very high, to ye end that we may compare ye divers motions of ye superiour and inferiour clouds, for otherwise it may be thought that two clouds differently distant from ye earth, go according to opposite directions, when they were driven towards ye same side, because that ye superiour = now appear to go gentlier than those below, when they go as swift, and that appearance of slowness may make one judge that they might go to ye opposite side: It may be supposed that ye east wind is properly but an appearance of wind, since ye motion of ye air goeth ye same way as ye surface of ye earth.

This contrariety of winds in one, and ye same place in different elevations of ye air may proceed from hence that a great wind wch is carryed along equally and wch by consequence is lesser and lower, may there incounter another wch occupies in ye air a much greater space, and then ye inferiour wind may force one part of ye other to wit that wch is near ye earth wch is permitted its free course in ye higher air where ye higher clouds are: but with two contrary winds are equally strong and of ye same bigness and height, they stop one ye other and make a calm at ye place of their incounter, and having there heaped up much air they purify it and make it elastic all, whence it happens that that air to get at liberty flows back on both sides and makes two other contrary winds wch have their origin in that place.

If there is a south wind in winter wch comes from sea it may push ye very high clouds because that blowing in a tangent line, ye more it goeth towards ye southern distant it is from ye earth; and at last having much condensed ye upper air, ye spring of that air may make a north wind near ye earth wch will push ye rains on sea; this I have seen happen many times. one may explain after ye same manner all ye winds wch reign thro ye earth by these different causes, both generall and particular.

As to storms and great tempests, it is difficult to explain them by ye ordinary causes. It is observed that when in summer there falls thick rains and great drops, they are always accompanied with a very violent wind wch precedes them some seconds, and that its violence ceaseth as soon as ye cloud is passed. I explain these stormy winds after some are capable to overthrow trees and carry away ye tiles of houses in ye following manner.

When two winds sufficiently lower incline one to ye other 15 or 16 degrees coming from sea, and wch having heaped up and pushed before them all ye vapours wch they meet with, and having formed each of them a thick cloud they come to meet one another, they condense ye air in ye same place of their incounter and make it very elasticall, and according to ye rules of percussion make it go swifter by one third than either of them; let us suppose that these winds go swift enough to make 24 feet in a second wch is ye ordinary swiftness of incommodious winds and against wch it is trouble to go, ye wind composed of two will go swift enough to make 32 feet in a second and ye thick cloud wch they push being elevated $\frac{1}{2}$ or $\frac{1}{4}$ of a

leagne, & drops of rain wch are formed there are about ye thickness of three lines
diameter and acquire their compleat swiftness to make 32 feet in a second after ye dec=
=cent of 100 feet as is explained in ye end of ye treatise of perspective, every drop fal=
=lin from ye hight of ye cloud drawes along with it two or three times as much aire as
it is thick: this is proved by ye experiment of a small lead ball permitted to fall into a pail
of water; how soon as it hath touched ye bottom of ye vessel there is elevated two or three
bubles of aire as great as it, wch cannot proceed but from ye aire wch follows it to ye bottom of
ye vessel. now it is known that in many places there is made use of certain bellows to
melt ye mineral of iron in ye furnace by ye help following of water, this is done after ye
this manner. there is a pine wood or tun of 14 or 15 feet high, and of a foot diameter
wch is fastned in a mossed tub turned upside down, wherof ye head is placed upon ye
ground: so that by ye little water wch there falls, it stops ye neither and ye aire cannot any more
enter there. there is left at ye top of ye pipe one hole of three or four inches diameter, in wch
is put a tunnel where ye neck is of ye same thickness and there is made to fall from 15, 20,
or 30 feet high ye water of some fountain, whereof its largness in falling is neer equall
to ye hole of ye tunnel, that water falling drawes with it much aire, wch follows it below
ye tunnel and to ye bottom of ye tub, wch cannot go out again there ye tunnell because of ye
weight of ye water, wch continueth to fall, and ye swiftness of its motion; there is put at ye side
of ye tub a pipe wch goeth straight to ye hole in ye bottom of ye furnace where ye coles ought
to kindle, and ye aire purged and mingled in ye tub, not being able to go out ye top because
of ye violent fall of ye water wch fills up ye hole of ye tunnell now there ye bottom because
of ye water wch is there collected and wch is elevated a foot or two above ye chinks wch ye=
=main between ye earth of ye bottom and ye staves of ye tub, it is constrained to go out with a
very great force there ye end of ye channell, so that it produceth ye same effect in blowing ye coales
as great bellows of leather ought it yt elsewhere. it ought therefore to happen wch falls from
ye cloud in great drops and in great abundance, will draw with it much of ye aire as hath been
proved, that aire cannot [illegible] we meant when it is near ye earth because of ye other drops
wch fall with violence: it cannot also extend it self towards ye back side of ye cloud, because it
is sustained by ye great wind wch drives it, now yet by ye sides or but very little, because of
ye same wind ye length of cloud by ye two sides. it remains therefore that all its strength be made
before of rain, and that this about joyned to that of ye wind wch carries ye cloud should be about
twice as swift as ye wind wch pusheth it, and that this augmented make more than 60 feet in a se=
=cond then it may contain three as is proved hereafter. it cannot precede ye rain above three or
four hundred paces ordinarily, for ye reason that hath been said, that a space of aire of such
swiftness as it should be moved, cannot continue its motion a good distance in a streight line, it
ye cause of ye impulsion ceaseth. I am confirmed in this hypothesis in seeing a league distance
a thick cloud from whence this rain fell vaine: for in that side from whence ye wind came ye
drops did fall almost always streight: but in ye middle and near of ye most drops, they made
angle of more than 25 degrees as in ye figure following, in which A B is ye cloud B D
ye coast from whence came ye wind, and G H ye drops most forward.

The same thing ought to happen by hail and also if it was very thick and ye grains very big, they would draw along with them much air from above below, and would make a tempest yet more violent, whose swiftness might be 45 feet in a second. Ye great winds wch are made without raine may proceed from ye combination of three or four causes, and they come ordinarily from ye south — south — west: it may therefore happen that at ye same time, there is elevated a great quantity of exhalation on ye coasts in Africa, and ye there very much heated for three or four days together, and ye northern countrys are cooled, and that ye moon descending towards ye perigæum from her greatest height of ye apo= =gæum, makes a reflux of ye air wch hath been carried by a north — east; these four causes probably will make a wind impetuous enough wch will reign successively from Africa to unto England.

I observed one day a great tempest at Paris coming from ye south, and I learnt afterwards by credible relations that two or three days before there was a furious storm towards ye coast of Algeu. that town is almost in ye same meridian with Paris, if that wind made 30 feet in a second, it might arrive in two days from Algeues to Paris. might arrive in two days to explaining ye hurricanes wch are felt almost every yeaw in some of ye sint Iles, we might have recourse to some other cause? 2o because that these tempests are much more violent and make above 100 feet in a second: 2o that they do not last but 7 or 8 hours; 3o that they no where else but in some one of these Iles; 4o that they begin ordinarily with a north west wch is changed successively into other winds, to wit ye west, south — west, ye south, ye south — east, ye north — east and ye north. 5o that there is found in ye neighbouring seas of these Iles a quantity of dead fishes and that there are felt earthquakes from all wch circumstances one may conje= =ture that from ye earth wch is at ye bottom of these seas, there is eruptions of nitrous and sulphurious exhalations in many places successively wch cannot be observed, because that vessels wch should be found in these places would be swounded; and it may happen that ye first eruptions having been made at ye side of ye land of ye continent of America, ye wind that they excite from ye north west may reflect against ye coasts of Caroline and those wch are near and there being made at ye same time new eruptions, ye first being ceased, ye wind ought to increase and come from ye west, as those assure us wch have there felt their effects; and these fiery eruptions and nitrous and sulphurious exhalations, ought to kill a quantity of fishes in ye places where they are elevated; they who have seen most of ye hurricanes, and who have observed many other circumstances, may explain them with more certainty.

The Second Part
of
the Equilibrium of
Fluid bodyes

Discourse I
of ye
Equilibrium of Fluid bodyes by weight

To explain well ye Equilibrium of fluid bodyes between themselves or with other bodyes one may use these following rules.

Rule I

A body doth not weight to be elevated up from ye bole, but in proportion to its dis=
=tance to ye center of ye earth, and a weighty body may be moved with a small force if ye distance is changed in respect of ye same center.

Experience may be made of it in this manner have a great pail full of water in a fitt place where there may be no wind make a great and weighty vessell G, swim on

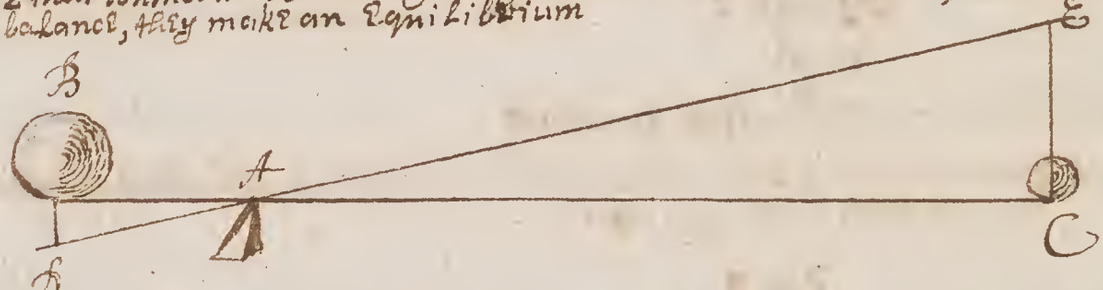
the surface of ye water and tye to it a small silk thread H I, and draw it so that it do not break that is to say with a very small force, ye vessel G will follow ye thread and although it may make small wauls in ye water of ye pail, and a little of that force for ye dividing may fail, it will not hinder ye vessell from going sufficiently swift when it shall approach ye point B if its motion is accelerated; it is true that if one would give suddenly a considerable swiftness to ye vessell G; it would break ye thread, and also a cord sufficiently strong, as it it was tyed to a body immoveable, because that a very heavy body cannot receive a great motion all of a sudden but by a very great force.

This truth will be yt confirmed, if a great weight is hanged at a long cord in an open place; for at least wind will give it a motion altho it cannot be moved without its being a little more elongated from ye centre of ye earth than when it is in quiet; from thence is seen ye reason why it is easily to sustain a body of heavy upon a plain much inclined, as if B be drawn on from A to B, it is not elevated in regard of ye centre of ye earth, but from ye line BC which is

imposed perpendicular to an Horizontal Line A C whereas if it had been elevated perpendicularly in ye same time unto a right equal to A B it should have acted by all its weight, and should had a much greater force to elevate it.

Rule 2

If two bodys with (respect) a spring of ye same matter dashing against one another horizontaly and directly have their quantitys of motion equal, that is to say if ye forces are reciprocall to their bulk, as soon as meet they will make an equilibrium, (it is supposed that ye bodys of ye same matter have their weight proportionall to ye quantity of their matter) according to this rule, if a weight of two pounds going with ye swiftness of four degrees meet an other directly and horizontally of 4 pounds weh hath two degrees of swiftness, they shall stop one ye other and make an equilibrium: but if ye first of 2 pounds ~~with many~~ goeth 6 times as swift as an other of 10 pounds it will carry it along with it, for ye product of 2 by 6 weh is 12, is more than ye product of 10 by one. from hence is easily proved that principall of ye mechanics, weh is not well proved by Archimedes Galileus, and many other authors viz that whence in a balance ye weights are reciprocall to their distances from ye centre of ye balance, they make an equilibrium



for Let ye balance be B A C, A ye centre of ye motion, A C quadruple to A B; ye weight B quadruple to ye weight C, I say that one of ye weights will not carry away ye other; for ye weight B it possible carry away ye other; but it cannot be moved with any swiftness that may make it descend thro ye arc B D, that will not make ye C go 4 times a swift thro ye arc C E, since ye semidiameter A C is quadruple to ye semidiameter A B, and then ye quantity of ye motion of these two bodies would be equal and a quantity of motion should throw force one that is equal to it, weh is impossible, since they ought to make an equilibrium by ye 2d rule. for ye same reason ye weight C cannot descend, for then it can give to ye other weight a less quantity of motion than that it takes it self, and by consequence will force it, and it is sufficiently strange that ye weight B being 30 pound and ye arm A B of a foot, one cannot sustain ye weight in put ye hand under, and that one shall easily sustain ye weight of one pound at 31 feet from ye point A if ye weight B is taken away, for it has but ye weight of one pound though one put it 100 feet distant from ye point A; and nevertheless if one put out ye same time ye small weight at 31 feet distance from ye point A and ye long one foot, ye small will weigh down ye great, weh cannot happen but because it is supposed to give in descending a less quantity of motion to ye weight B than that which it takes, and that they both act and will all ye force of their weight by ye first rule, because they have ye same direction towards ye centre of ye Earth.

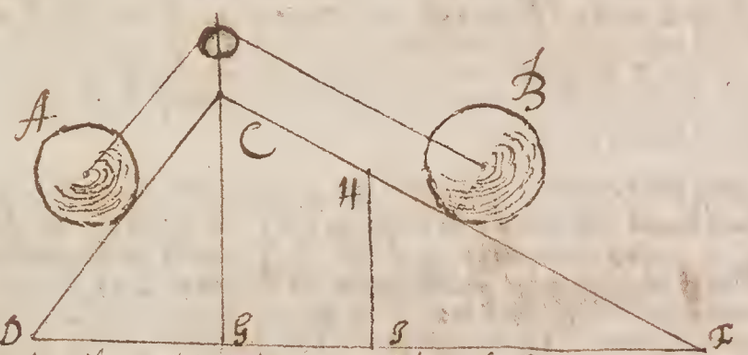
Rule III

when two weights have not ye same direction towards ye centre of ye Earth and that they are so disposed that one cannot move without moving ye other as swift, one must not esteem the forces of each by its simple quantity of motion, but by a respective quantity of motion which is found by multiplying each weight by its swiftness in regard to its approach, or its motion from ye Centre of ye Earth. As if a weight hanged to ye pully B by E B A, weh sustains also ye bowl E b by means of two small cords joyned to C. I affirm) of ye bowl and to ye point E of ye cord A B E. # G is an horizontal line, # F is perpendicular: E B is parallel to ye inclined plain G F. It is manifest that ye bowl is disposed to go as swift as ye weight A let ye weight A descend or ye bowl by descending make it mount upward, but when it hath passed thro ye space F G in descending obliquely, it will not approach ye centre of ye Earth but ye distance F #, considering all ye points of ye Line # G of two or three feet long as it it were equally distant from ye centre of ye Earth, because that ye difference is insensible. to ye end therefore to know

ye forces of these weights in their respective quantitys of motion, we must multiply ye weight of ye bowl C B by ye length C F and that of ye bowl A by a length equal to C G since that bowl makes as much way in mounting on in descending as ye bowl C B, and that ye bowl towards ye centre of ye earth. but if C G is triple to C F and that ye weight C B is triple to ye weight A, there will be an Equilibrium between these weights such proceeds from ye causes explained in ye two first rules: but if there is added any small weight either to ye weight A, or to ye weight B, it will descend and make ye other mount up drawing ye pully and ye line w

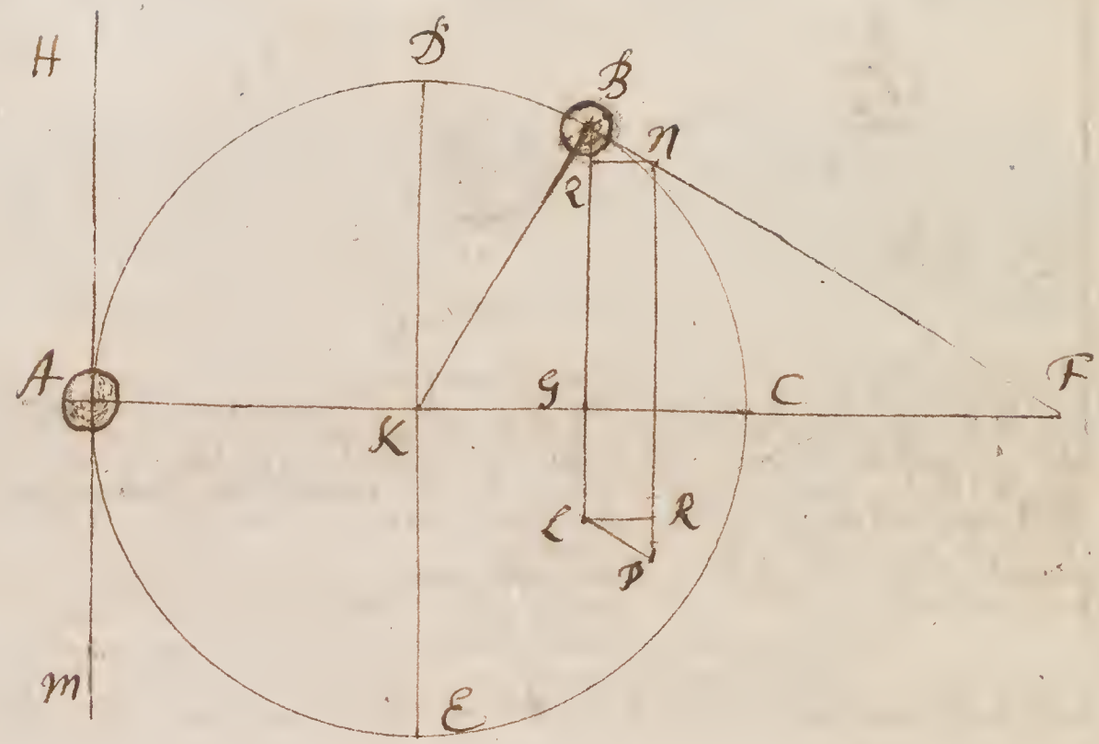
After ye same manner may be explained ye Equilibrium which ought to happen when ye plain F G shall be more or less inclined by applying these ye same rules, which one may call principalls of experience or laws of nature.

As if ye weights as A and B in ye following figure are upon planes differently inclined as C B, C F, B F being supposed horizontal and C G perpendicular to B F it will neerest to make an Equilibrium that ye weight B may be to ye weight A as ye Line C F to ye Line C B and it is



proved by ye same rules how ye C H is taken equall to C B and that H I is drawn parallel to C G it is manifest that while ye weight B should from F to H, ye weight A should go from ye C to D therefore C G should be ye measure of ye swiftness of ye weight A in regard of ye centre of ye earth, and H I that of weight B going from F to H in ye same time; but as F C to H G so is C G to H I, and by ye third rule ye weight B ought to be ye weight A as C G to H I, that is to say as F C to C B to make an Equilibrium. and by consequence these weights so disposed will stop one ye other.

The same thing will happen to two weights tyed to ye ends of ye spokes of a wheel that is to say to ye end that of weight A situated at ye extremity of ye spoke K A may make an Equilibrium with ye weight B, ye Line A K being horizontall and ye Line B K elevated 60 degrees above A K F. It is necessary that ye weight B should be double to ye weight A if ye Line B F being drawen perpendicular to ye spoke K B until it meets ye Line A K G F, ye plane B F shall be elevated 30 degrees, and ye perpendicular B G shall not be above half of B F these = fore if motion of ye weight B towards F being made at ye beginning according to ye tangent B F will not be advanced towards ye centre of ye earth but ye space B G ye half of B F whereas ye weight A will have its direction according to ye tangent m A H perpendicular to A K F which is removed directly from ye centre, and by consequence will be disposed to go two times as swift



in regard of ye same centre as ye weight B: but as F B, to B G so ye Spoke K B or A K to K G; whereforé ye weight B shall make ye same effect in regard of ye weight A, as if it were in G, that is to say that if A K is ye measure of ye swiftness of ye weight B, but A K is double to K G, as F B is to B G; therefore ye weight A shall be reciprocally to ye weight B as K G, to K A and by ye second and third rule, and by ye second and third rule, these weights so disposed shall make an Equilibrium and one will not forge ye other.

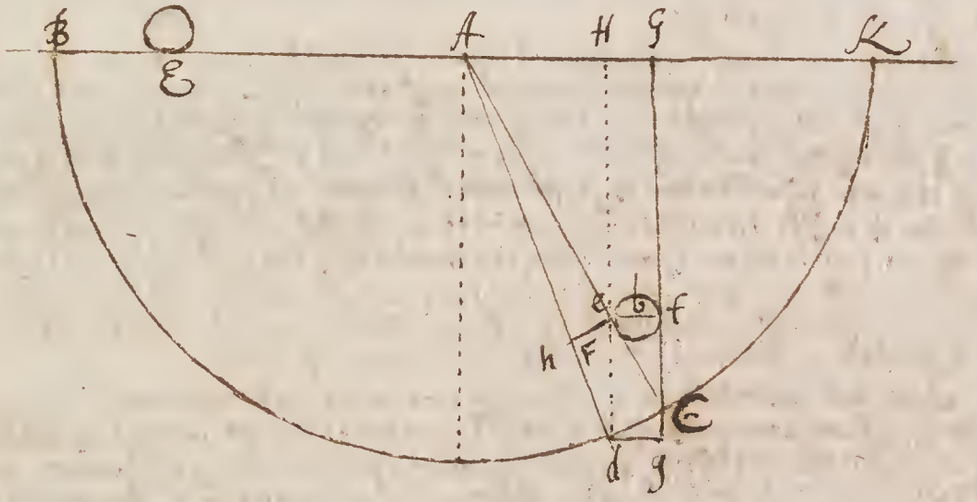
The same thing will happen to two powers, weh being tyed to ye extremity of equal spokes of a wheel shall draw obliquely or directly: for let there be at ye point L in ye line B G continued directly to L a power drawing by ye cord L B joyned in B according to ye direction B L and another power in m drawing according to ye tangent line A m by ye cord A M tyed to point A. If these powers are they will not be in Equilibrium: but ye power in M will force ye other, and to make an equilibrium, it is necessary that ye power in L may be to ye power in m as like A K to K G, weh proceeds from hence ye power in L doth not come to it selfe directly to point B: but it goeth according to ye tangent B F at ye beginning of ye motion, and that in ye same time ye power in m goeth directly according to ye tangent line A m. now if B n is supposed infinitly small in ye tangent B F and that n Q may be perpendicular to B L, it is evident that ye point B being in m, ye point L shall become to P, if n P is parallel and equall to B L, and L R and Q n being parallels to A F, R P shall be equall to B Q, and L P to B n; now ye power tyed to ye point m shall be advanced according to ye direction of ye effort A m a line equal to B n or L P and ye power in L shall not be advanced in ye same time according to ye direction of ye effort B L or L P, but of ye line R P weh is but halfe of B n or L P, as B G is but halfe of B F; whence it is necessary to make an equilibrium betwixt ye two ~~points~~ powers that weh is at ye point L may be double to that weh is at ye point A, weh drawes according to ye tangent A m, and ye other according to ye direction B L weh makes an angle of 30 degrees with ye Spoke K B, after ye same manner it is necessary that ye weight B be double to ye weight A to ye end that they may make an Equilibrium.

From these three principalls of experience there is drawn a general rule for all ~~not~~ moving powers. this rule or universall principle is thus.

An universall principle of ye Mechanicks

When two weights or two other powers are disposed so that one cannot be moved without moving ye other, it is evident wch one of ye weights ought to run thrô according to its proper and naturall direction is to ye space wch ye other ought to run thrô it in ye same time according to its proper and naturall direction, wch I propose call as ye last weight is to ye first; there shall be made an Equilibrium betwixt ye two weights, but if one is to ye other in a greater proportion it will force ye other.

One may prove by this principall a surprising effect wch cannot be proved easily by other Hypothesis; viz that if there is many equall arms joyned to ye same C as A B, A C, and a weight E is put upon ye arm A B and another b upon ye arm A C at



the point F so that ye distances A E, A F may be equall ye weight in F being weird and not tyed to ye point F, so that it may work from F to C but that it is hindred by a staff g C g placed perpendicularly; then to make an Equilibrium it is necessary that ye weight E be much more Lurge than ye weight b, viz in ye proportion of A E to A H, if H F is a perpendicular line to B A g K, wch is contrary to what happens when ye weight F is tyed to ye inclined plane A F C how is then necessary to make an Equilibrium that ye weight F may be greater than ye weight E in ye same proportion of E A to A H as hath been explained in ye preceding figure.

To prove this paradox draw ye line f b E horizontal passing thrô ye centre of ye bowl b, it is evident that ye point E is higher than ye point of ye suppositor F, and that b E is some what Lurger than ye semidiameter b f; but for to make ye demonstration ye triangle F h d is supposed infinitely small, and ye point F joyned to ye point E and that of perpendiculars F h passeth thrô ye point c now ye bowl b in descending shall be turned round ye point C by ye arc C A; and if d g is equall to ye diameter of ye bowl, ye same arm shall be in ye situation A h d when ye diameter of that bowl shall be arrived to d g and ye point of ye suppositor F shall have described ye arc F h at ye same time as ye centre of ye bowl shall be descended thrô a space equal to e d; but it becaus of ye smallness of ye arc there is taken ye arc F h for its tangent, one shall have ye triangle F h d Like to ye triangle A H F, and d F shall be to F h as F A or E A to A H, and because that ye weight E in proportion to ye Line F h, ye space passed by ye bowl in descending directly from ye point F unto d shall be to ye space passed in ye

same time by ye weight E in mounting directly, as A E to A H, wherefore ye weight E to make an Equilibrium ought to be to ye weight B as E A to A H by ye universall principall; and because that ye bowl falls yet a little higher than ye point F viz. from ye point E, it follows that ye weight being in that proposition ye weight B shall descend and elevate ye weight E, as I have found it com= = manded by experience for having supposed ye arm A C so that it might make an angle of 60 degrees with ye horizontall arm A H K, I have observed that ye weight B being double to ye weight E it would make an Equilibrium with it when I had proyed to hinder its vaulting, but having given it freedom after I had put a looking glass represented by C G fixt to hinder its vaulting outside, it was necessary to put ye double weight in E and ye simple in B to make an Equilibrium, and also to add a little weight in E. It will be proved by ye same propositions that if ye angle K A C was 48 degrees it would be necessary to make an Equilibrium that ye weight E was ye greater in pro= = portion of ye diagonal of a Square to its side. there is not there considered that ye center of ye bowl of F is a little at ye side of ye point of support.

These things being supposed, one may sufficiently well explain ye Equilibrium of fluid bodies.

The Lightest that is to say ye least heavy of fluid bodies is ye flame, but because it is elevated into ye aiv, and that it is not extended upon other bodies it cannot make an Equilibrium by its weight, but only by its shock and by its spring.

The aiv wch is extended about ye Earth and waters, can make an Equilibrium by its weight, by its shock and by its spring with other more gross fluid bodies, and also with firm and hard bodys. ye weight of ye aiv is proved by ye effects of ye Barometre, that is a streight pipe of glass of 2 feet and $\frac{1}{2}$ or 3 feet long sealed Hermetically at one end it is filled with quick silver without permitting any aiv, and ye other end is stopt with ye finger, and after ye sealed end is turned upp= = ward, ye finger is dipped into Mercury put into a vessell, ye finger is taken away wch ought to sustain ye Mercury in ye pipe, and then one part falls into ye vessel, and after some vibra= = tions it is stopped at last in ye pipe at ye height of 27 or 28 inches: but according to ye changes of winds and ye aiv, it mounts sometimes to 28 inches and $\frac{1}{4}$ and at other times only to 26 $\frac{1}{2}$ and ordinarily it is stopped at Paris at 27 inches and about $\frac{1}{2}$ a halt.

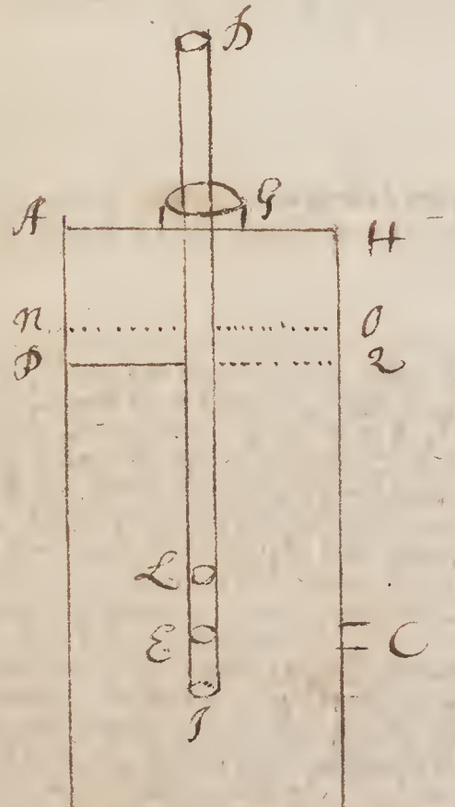
Now that Elevation of ye Mercury cannot be well explained, but by supposing that ye column of aiv of ye same largeness as ye inward diameter of ye pipe weighs as much as ye 27 or 28 inches of Mercury elevated in ye pipe, in taking that column from ye surface of ye Mercury wch is in ye vessel to ye extremity of ye highest region of ye aiv; now if ye Barometre is carried to ye top of a mountain or of a very high tower, ye height of ye Mercury is seen a little to diminish, and be reduced to 24 or 25 inches, as being then charged with a less quantity of aiv; and if we descend into caves or very deep mines, is elevated by little and little as we descend as being successively charged with a greater quantity of aiv.

The weight of ye aiv and ye Equilibrium wch it makes with water may be known by ye same rules supposing that an inch of Mercury weighs as much near as 13 inches of water as I knew by ye experiments wch I made: for 28 inches of Mercury weighs almost as much as 393 inches of water, wch make somewhat less than 32 feet; whence it follows that when ye weight of ye aiv will make ye Mercury mount 28 inches and some lines, it will make ye water in a pipe of 35 or 40 feet mount to 32 feet, and that when it is elevated but to 27 $\frac{1}{2}$ inches; ye water ought to be elevated but to 31 feet or near, wch is found to condown to some experiments wch I have made at ye observatory in ye following manner. I caused Mr Thevin to make a pipe of glass of 40 feet high wch was fitted to a hollow piece of wood, to ye end that it might not be broaken in ye handling, it was of 5 or 6 pieces wch he fortified in ye great Hall of ye observatory, and one of ye ends was elevated to ye top of ye platform thro ye hole wch is there for such engines perpendicularly to a hollow place of a top of ye cave; it descended by little and little into that hollow and was made fast by tying to iron in many places then having been filled with water after ye lower most end was stopped, there was applyed to ye top a glass stopple wch might exactly stop ye pipe and there is put more over a bladder for ye better sealing; a small vessel was likewise filled with water wch was below ye other end to that it might be immerged in ye water, and after it was unstopped, ye water falling descending to about 12 feet, but there went out so many bubbles of

aire that that knew how it remained at ye hight of 29 feet because of ye spring of ye aire of
bubles wch were seperated from ye water and mounted to ye top of ye pipe. two dayes af-
=ter there was put into it water wch had been boiled a little before to seperate ye aerine
matter; ye experiment was made after ye same manner, and ye water after some vibra-
=tions stopped at 29 feet and about 4 inches, it is seen to mount higher by little and little
and to stop at 30 feet 2 inches, ye other Barometers not being changed. I attributed ye
cause to this that ye water wch had been put in was mixed a little with dirt, and by conse-
=quence weighed heavier than clean water; but that dust descended in a little time to ye
bottom of ye small vessell; and by that means ye water becoming lighter it ought to rise some-
=what higher. two dayes after I observed that ye common Barometer being at 27 inches 9
lines, ye water of ye great pipes was risen to 30 feet 8 inches, it would have mounted a little
higher if there had not been elevated some bubles of aire wch might keep it down: ye common
Barometer being at 28 inches it mounted yet higher, and descended afterwards when ye com-
=mon Barometer returned below 28 inches, whence I know that ye Barometers of water have
their changes proportional to those of Mercury and that one may take 32 feet of water
for ye greatest hight (or near it) of these Barometers when ye water whose with they are filled
is ye least weighty and that ye aerine matter is thence seperated.

For ye ease of calculation let us suppose if ye weight of ye atmosphere makes perfectly
an Equilibrium with 32 feet of soft water, and if ye Mercury weighs 14 times more precisely.

The weight of ye aire may be moreover known by an experiment sufficiently curious:
take a glass bottle A B in wch make a hole of 2 or 3 lines at B in C; put in ye neck G a pipe of glass
D E about 2 lines diameter and solder it was a mixture of wax and turpitine on with filter
so that ye aire cannot pass between them; then fill ye bottle with water thro ye ouverture C in its
lying down and also ye pipe D to keeping stopped ye end D, and when ye bottle is put in its perpendicular



situation ye water wch is in ye pipe descends unto E
and goeth out by ye hole C if ye extremity of ye pipe
is of ye same hight with ye middle of ye ouverture C;
but if ye pipe is extended below ye ouverture as unto
I ye water will cease to run ye pipe being emptie
unto E and ye bottle shall remain full of water
unto ye solder towards G; but if ye end of ye pipe is
higher than ye top of ye ouverture C as in L, and
that it is 2 or 3 lines lesse then ye aire shall be
seen to go out thro ye open end and ascend to
top of ye bottle and ye water shall go out at ye
same time thro ye ouverture C until that it is not
much above ye point C, these effects are explained
in this following manner

The weight of ye exterieur aire makes an effort
towards ye ouverture C to push back ye water which
makes an effort by its weight to go out and ye aire
wch is about ye pipe E B makes also an effort and
acts by its weight upon ye water wch is there con-
= tained; and being joyned to ye weight of ye water it
ought to force ye weight of ye aire wch acts towards
C, wch makes ye water of ye pipe descend into E,
and then ye aire makes an effort from one side in
E and from ye other in C and consequently sustain
ye water of ye bottle from E into H, and it
will keep up that place through ye hight C H (which
of ye hole C; but when ye pipe descends but to L then ye water from L unto E joyned to
weight of ye aire wch weighs upon E touches ye aire in C and ye water runs thro C, while ye
aire descends from B to L and enters down by drop in ye water by ye open end L, and is elevated
be 30 feet above ye point of ye pipe being between ye bottom

to ye top of ye surface of ye water, wch is below ye neck of ye bottle; if we incline ye bottle so that ye point L and ye middle of ye curvature C may be in ye same horizontal line, we shall see part of a drop of air wch will fall below from ye point L but wch will not be separated from ye rest if we do not incline ye bottle a little upright.

When ye air is permitted to enter into ye bottle so that ye surface of ye water may be in n o and that air is heated with ones hand to make it be dilated there goeth out some drops of water then, although ye end of ye pipe should be below that curvature, and ye water will descend to p q but if ye air is permitted to cool, we shall see during some time drops of air enter through C because that ye air wch was descended unto p q returns into its former extent from n o unto ff, and having not enough water to fill ye space n o p q, it is necessary that ye air should come thither from without thro ye curvature C.

The water hath not any sensible spring and makes an equilibrium with other matter only by its weight or by its shock, ye fourth equilibrium that may be observed in respect of ye air, is that being united to very small drops, it becomes higher than ye air, and is elevated in vapours as hath been said before. It cannot be said how small a parcell of water ought to be to make an equilibrium with ye air near ye earth, because that those wch are a little heavier or a little higher than that air are perpetually miscible. It is also hard to find ye cause of their elevation, for it is not ye mixture of ye air since they should weigh yet more than ye pure air; it is not ye heat, because very cold water is found to cast out vapours. It may be supposed that there is small pores in ye air, where there is not any heavy matter, into wch ye small parcells of water may insinuate and mount that way, and those wch are a little too = -esse cannot pass. Those small parcell make at last an equilibrium with ye air, at ye distance of a league or 2 from ye earth, and they remain there a long time suspended until that many being joined together become heavier, and if ye should be very much agitated they might fall.

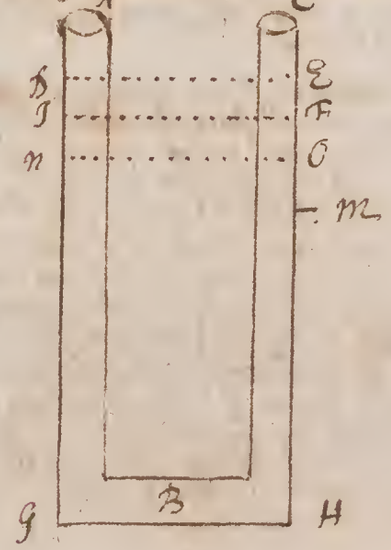
There is seen an experiment in ye Pneumatic engine; for when one part of ye air is pumped, ye recipient is seen troubled by ye fall of vapours wch cannot be any longer sustained in ye air, because of ye two great water-tractions, falling in small drops upon ye glass that encompasses them. in ye places where there is great falls of water, there is seen vapours to be perpetually elevated wch are nothing else but ye parcells of ye water broken by ye shock; and when a bubble of soap comes to be broken, one part of ye matter of wch it is composed, falls, and ye rest wch is reduced into very small drops, is elevated as ye vapours.

RULE I

For ye equilibrium of water by its weight. water being in a vessell or in many wch communicate one with hath always its ~~same~~ upper parts in ye same level; that is to say, in equal distance from ye center of ye earth.

Explication.

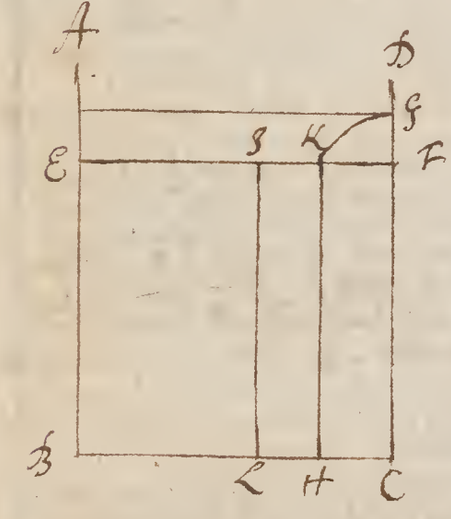
Let ye crooked pipe A B C of an equal thickness, in wch water is poured through ye neck A, it will mount as high in ye other pipe; that is to say that if D E is an horizontal line, and that ye water in ye branch A G mounts unto D it shall be in ye pipe in E, when we have ceased to pour, and that ye water shall remain in repose. for first if ye branches are equally large and equally inclined to ye horizon, all being equall on both sides ye water cannot remain in unequal heights A a, because that ye weight of ye water A shall be greater than that of ye water H c; and by consequence in descending it can take a greater quantity of motion than it can give to ye other in mounting, since their swiftness will equal and their directions like. whence by ye universal principal, ye water cannot be stopped if it is not at ye same height in these two branches. but if one stop with ones fingers ye end C before ye water is poured in by ye end A, and we fill with water ye branch A G unto A, ye other will remain void and there will none or very little water rise because of ye air wch possesseth it, if ye branch A G is not but two or three feet high; then if one take away ye fingers ye water of ye branch A G



will descend, and part pass into ye other branch, and will be elevated as unto E while from ye other part it will descend as unto n; and again mount to B, and descend to M; and at last after many balancings it will be stopped at ye same hight one both sides as I F.

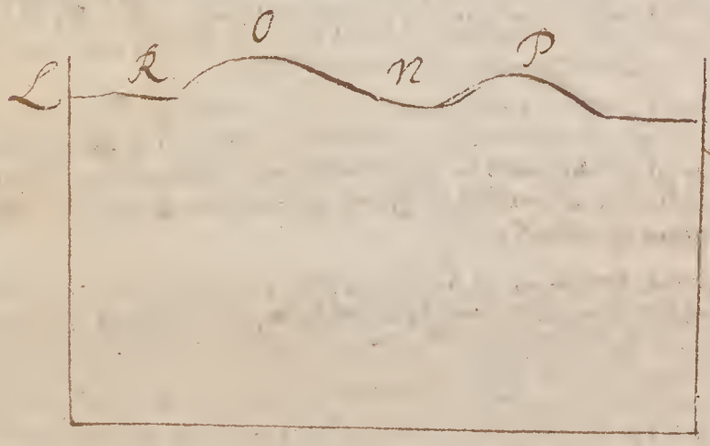
When in that experiment ye water begins to descend from ye branch A to pass into ye other, it accelerates its motion until it may be in an equal hight in ye two branches, as in I and F where there ought to be an equilibrium, and afterwards diminisheth its swiftness by little and little, untill it may be in ye points n and E. it will after ye same manner descend in accelerating from ye top E untill it shall have passed ye same Level I F and will diminish its motion till one of its hights be in B and ye other in M, these ballancings will continue till ye water may be stopped in I and F, after ye same manner as ye head of a pendulum accelerates its motion unto ye point of repose, as it diminisheth it in remounting, and as it at last stops at Last after many ballancings.

The same thing will happen in a vessel A B C D where there is water unto E F now if we powr water towards F, so that it is elevated to G, it will not remain in that estate when we shall cease to powr new water: for ye weight of ye water G K H C, being more than that of ye water K I L H, L H and H C being supposed equall it will force ye water

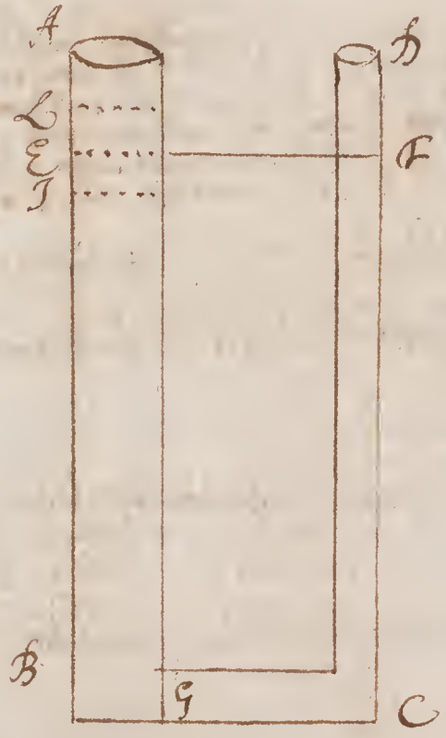


force it Last, and elevate ye water towards I K and in ye same time ye superficies surface G K being steep, ye water shall run from G towards I; and for ye same reason ye water I B L I shall be also elevated: and at Last after an any motions ye surface of ye water shall be even.

From thence may be explained that wch happens in standing water L M, when there is cast in n, for ye stone making ye water rise about it in a circular wave whereof O and P represent ye elevation, it cannot remain in that position, but ye part O will run towards L, and in running it will push and elevate ye neighboring water R, which will push and elevate ye next, so that it will seem that ye water raised in O is advanced unto L ye same thing will happen to ye P, and by that means it will make a circular wave wch shall be removed from ye point n enlarging it self to ye banks L and M, if ye are not remote and thence being reflected, it shall make a new circular wave, wch shall advance from both sides towards n, and shall encrease in circumference diminishing in hight till all ye upper part of ye water be even.



Let now ye two branches be unequally longe as in ye figure A B c b, ye wa= =ter shall nevr ye less be at ye same hight as E F in ye two branches, and ye water E B shall not force ye water C F; for let ye base B G wch is supposed forevr be 16 times greater than ye base C, and if it is possible let ye water descend from E unto I, and that it mount on ye other part unto b, that wch shall be descended from E to I, shall be equall to that wch is in F b, and ye two small cylinders F b, E I will have their hights reciproc= =all to their bases: therefore 16 : 1 :: ye hight F b: E I: now ye cylinder E B being 16 times as great as ye cylinder C F it shall weigh 16 times more; but ye space passed in ye same time by ye small cy= =Linder, shall be 16 times as great as ye space passed by ye great cylinder, and their directions are ye same being perpendicular, therefore their swift= =ness should have been reciproc to their weight, and they should have had an equal quantity of motion, wch is impossible; for by ye universall principall these cylinders of water ought to make an equilibrium, and ye one cannot move ye other since they are disposed to take an equall quantity of motion according to ye same direction.



But if water is powred into ye narrow pipe unto b, it cannot stop but when ye other branch shall be full unto ƒ; for let ye hight F b be one inch and its base one inch and F C 16 inches, therefore all ye water C B shall be 11 cubic inches, and ye water C b descends an inch, ye water E B shall mount $\frac{1}{16}$ of an inch, viz ye hight E I and ye space E L shall be ye measure of ye swiftness of ye water B E, as b F is that of ye water C b: now 1 so multiplyed by $\frac{1}{16}$ gives ten for ye quantity of motion, and 11 multiply by 1 gives 11; therefore ye quatity of ye motion of ye water b C shall be greater than that of ye water B E, on wch is ye same thing, ye swiftness of ye water of ye little branch hath a greater reason to ye swiftness of ye great branch, than ye weight of ye Last to ye weight of ye other; and by ye universall principall ye water of ye small pipe will descend. ye same consequence will be drawn for ye other unequal heights untill that ye two surfaces of ye water in these branches may be even, and they will not stop one ye other before they be of ye same height.

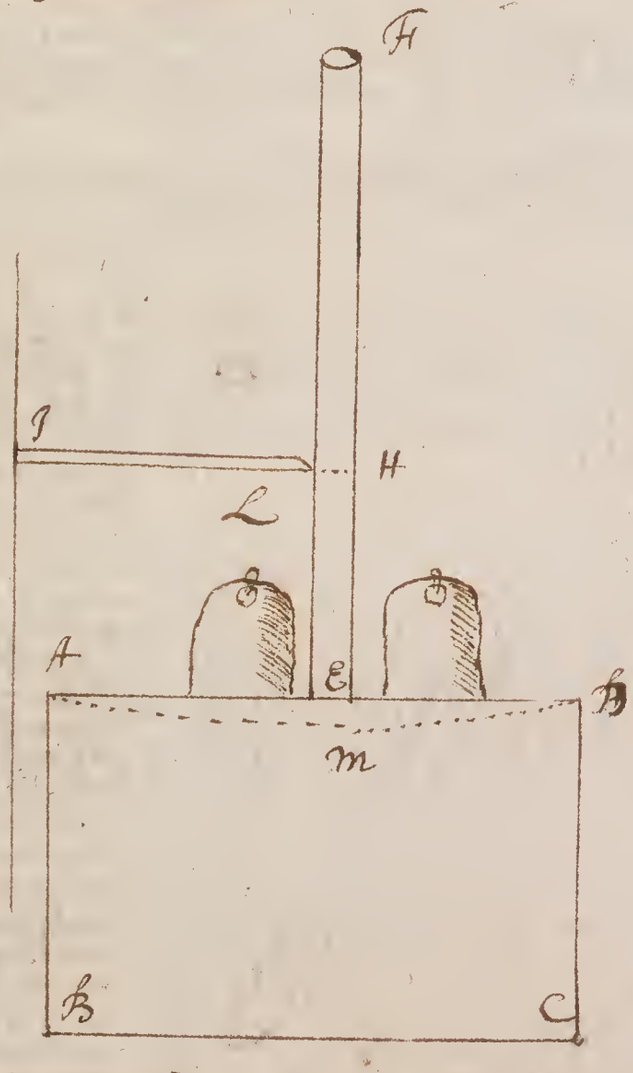
One may moreover consider ye water in A G as if it was divided according to its length into 16 small square columns each equal to ye small square column C b: and because that each of these columns cannot mount higher or descend lower than ye other, one may judge ye same of ye small column C b, although they are not contigues.

Hence it follows that if we put a floating body upon ye branch A B, and that the weight of that body may be equall to that of ye water wch occupies ye height A E when it should have been taken away, ye water of ye small branch shall remain always at ye height C b, and shall make an equilibrium between ye water C b and ye water C B joyned to ye weight or floting body for ye same reasons as above.

When ye Little branch is very small as of half a Line, or one third of a Line, ye water mounts there higher than in ye other branch of an inch or two, wch happens also when in ye water a pipe glass, whose diameter is less than ye 4th of a Line; for it is there elevated after ye same manner ye height of ye height of an inch or two above ye rest of ye surface of ye water, and all that water wch is elevated above ye rest Level in ye small pipe or in those wch moderately large as of a Line half a Line insensibly equall to ye weight drop of water wch being joyned to some bodyes remains hanging without falling

The same effect is seen in ye experiment of ye bottle above, for if ye pipe is very slender, as of half a Line, ye water will not descend ~~for~~ but towards L about an inch above E, and then ye new tincture caused of adhesion resists ye pipe; and ye slender ye pipe ye more elevated will ye point L be.

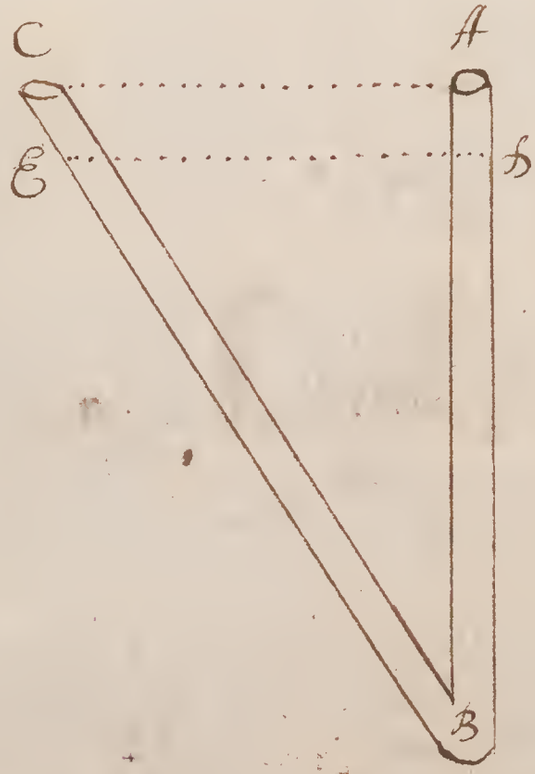
Some attribute ye cause of that effect to ye weight of ye aire wch acts fully upon ye water of a large pipe, and cannot well act upon that of a narrow. but we must reiect that cause: for if one plunge a like pipe into Mercury, it will not mount any higher than ye Level of ye rest of ye Mercury, and nevertheless ye weight of ye aire ought to act ye same as in respect of ye water: and also if we dip into water one of ye slender pipes wch hath not but half an inch height, ye water mounts to ye top, altho ye aire hath then no trouble to insinuate it self there: add to this that if ye pipe is gross or that it hath been let alone along time without using, it contracts a certain kind of slabbering that ye water cannot stick. and then ye water is not elevated above ye Level altho that cause of ye default of ye aire remains of some without changing. It is nevertheless therefore to explain that effect by ye same causes as elevate ye water wch is in a vessel of wood more than a Line and a half towards ye brim with a small concavity and wch ioyns two drops of water one to ye other when they touch, of wch causes there hath sufficiently been spoken in ye first discourse.



A surprising effect of ye equilybrium is seen in ye following experiment. take a vessel of wood of two or three feet long A B C b full of water: make a hole in ye top as in E thro wch put a pipe of an inch Lange, ioynd well with pitch and flax or some other matter, that ye aire may not enter, and that ye streight pipe, viz E F is 12 or 15 feet high: fill ye vessel with water thro some holes in ye top, and place upon ye top 100 or 600 pound weight that it may bend it concave as A m b if you mit a white mark to ye side of ye pipe as at H, and a little height a nail I L fixed in ye neighboring wall and fastned so that it may remain immovable. by pouring ye water by little and little into ye pipe E F, you shall see that when it is full ye end A m b will be elevated with ye weight at 600

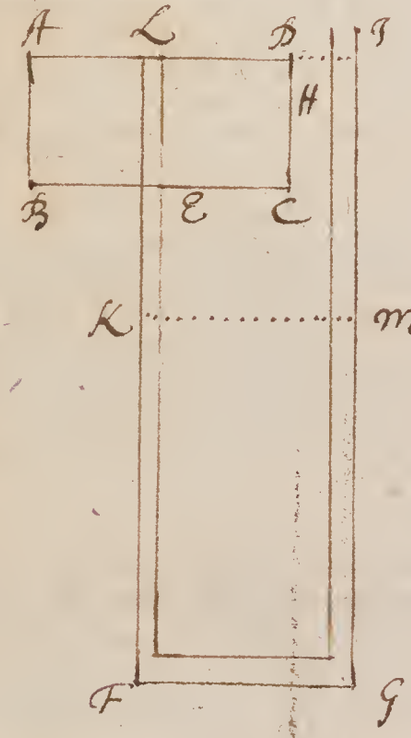
pounds wherewith it is charged, not only to its first estate A E b, but will also become convex, and its elevation in ye middle shall be above ye point E as much as ye point m was before below; this is known because we shall see ye white mark H elevated, and pass a little higher than ye mark I L whereby one may measure ye difference. but if ye pipe is yet higher ye of ye weights shall be yt water: whence may be judged that yt little water with is in ye pipe. hath as much force to elevate that great weight and window ye end of vessel con= =vex, as if ye pipe was of ye same Largeness as ye vessel: this effect will be proved by ye same reasons as above concerning ye water of ye small branch c B, wch elevates ye water of ye branch B A, when it is but to E, altho it should weigh 1000 times more: for ye swiftness wch ye small pipe c E will take in descending, shall be to that of ye bottom A b with its weights in elevating, as ye surface of ye vessel is to ye surface of ye pipe; that is to say that if ye pipe is an inch diameter and ye vessel 30, ye surface of head piece of ye cask shall be 900 times greater than that of ye height of ye water ye pipe therefore if ye water of ye pipe descend one foot, that wch toucheth ye upper part shall be elevated but $\frac{1}{900}$ of a foot; and by conse= =quence if ye water of ye pipe weighs one pound, it shall make 900 of a foot; and by conse= pounds, therefore it shall elevate ye 900 pounds wch are upon ye vessel with ye little wa= =ter wch will pass to ye top of A E b; but we must suppose that ye top is elevated altogether at ye same time for ye fitness of calculation and reasoning.

When in a Syphon one of ye two branches is inclined, and ye other perpend= =icular ~~is~~ being both near of ye same bigness ye water will be there also level; for



Let ye Syphon A B C be placed so that ye branch A B may be perpendicular, and that c B may be in an inclined plain, it is manifest that ye weight of ye water wch shall be in b B, shall be to ye weight in E B as ye quantity of b B to ye quantity of E B: but E B is an horizontal line, ye whole force of ye water E B to descend shall be to that wch it would have had fal= =len perpendicular as ye Length E B is to ye Length b B: therefore it shall make an Equilibrium with ye water b B whose direction is perpendicular accord= =ing to ye universall principall: for ye spaces passed in ye same time by ye water of ye two branches according to their naturall direction towards ye centre of ye Earth, will be in a reciprocal reason to that of their weights, that is to say of E B to b B, and by consequence ye water E B shall not force ye water B b, ye greater ruling in ye Long branch may make some difference, and give some what more trouble to move ye water by ye inclined plain E B: altho one of ye two branches should be Longer, it will not hinder ye Equilibrium for ye same reasons which have been said above.

When in ye syphons wch have one branch much
more Longe than ye other, as in ye following figure,
and ye stop ye end of ye small branch with ones fin=
=ger, and that ye great one being also that filled with
water, yet suddenly take away ye finger, ye first mo=
=tion of ye whole water A B is retarded by ye difficulty
of ye passage in G but ye motion through F C is much
further in ye beginning than when ye two branches are of
Equal Lowness: whence it happens that if we put a
little water into ye branch F C, until it hath filled
ye pipe of Coniunction B c and it after ye end F hath
been stopped with ye finger, we fill ye other part A B to
ye Horizontal Line E D, and that we next take away
ye finger on ye sudden, ye water will mount higher
than D as into F, wch happens because that ye water
of ye great branch altho descending gently makes ye
water in small branch to mount 3 times as swift, and
that all ye water moving to make an Equilibrium, it did
yet move after it was arrived there by ye acquired fw=
=iftness as in an uniform syphon. wch makes ye water
of ye great branch yet descend and ye other mount to two
or three inches above D, whence it redescends and after
some ballancings is stopped at Last at ye same height in
ye two branches below E F; and though ye pipe A B shall
be full before ye stopping with ye finger, ye water would
nevertheless mount 2 or 3 inches higher than F if
ye branch A B is Longer than ye branch c D; for then ye descent and mounting in that Longe branch
shall be very small and almost insensible; how it is ye experiments wch have been made.

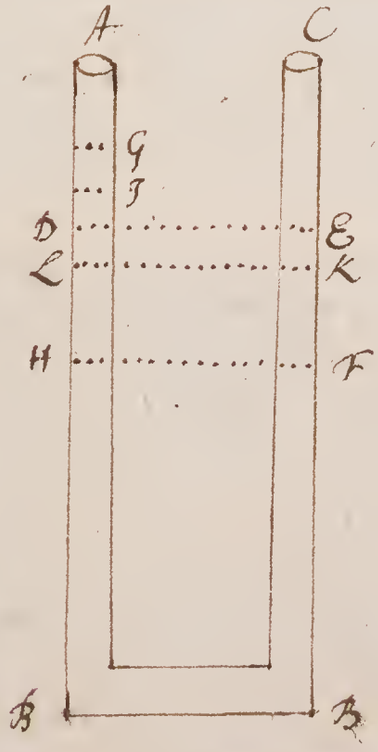


We did take a vessel of tin A B c D with ye pipe E F of 4
inches wide wch was soddered to ye crooked pipe of glass
F G H; we filled ye vessel and ye pipe E F after having
put my finger in H to hinder ye pipe G H. and when
ye finger was taken away, ye water spouted unto
about three inches height higher than ye surface of ye wa=
=ter A B; but when ye pipe of glass shall be 5 or 6 inches
higher than A D, ye water will mount there to about
4 inches higher than H; whence it will descend again
and at Last make an Equilibrium. there is made ye same
experiment in a pipe L E of Equally Longe thro but G H
remaining always streighter than L E F, and ye water
shall mount higher than ye point H, as when ye vessel
A B was on ye top of D F; now in these cases ye water
begins to mount sufficiently swift thro G, and mounts
yet a little further when ye water L E hath acquired
motion. but that swiftness thro G H begins to diminish
when ye water of ye two branches is arrived to an Equi=
=Librium, that is to say in to ye height where it ought
to stay in ye two branches as to that of ye Horizontal
Line K M. but if we put different Liquors in ye two
pipes, ye lightest will remain elevated in ye pipes hei=
=ght than ye other according to ye reciproc call pro=
=portion of their weights, of wch see ye rules.

Rule of ye Equilibrium of different Liquors by their weight.

We consider in this place two sorts of ye weight of bodies, one wch proceeds from ye mass of ye body, as a cubic foot of wood weighs more than a cubic inch of ye same mat= =ter, ye other proceeds from ye density of ye matter, or from some other cause by wch a body weighs more than another of an equal bulk, as a cubic inch of gold weighs more than a cubic inch of iron, we call ye last weight of specific gravity, so specific gravity or weight of water is greater than that of oyl; we do not consider here ye weight of ye aire in which ye body is weighed, al= =though in strictness it ought to be considered.

In ye Syphon ABC Let there bee an Equilibrium of water to ye height DE, then powr gently oyle into ye branch cB untill it is at ye height C, it shall happen there of water will descend below E, and be elevated above D in ye other branch; let ye descent be EF, and DG ye elevation, and draw ye Horizontal Line FH then ye oyle FC shall be to ye water HG reciprocally as the specific weight of ye water is to that of ye oyle; for ye water FB shall make an Equilibrium with ye water BH, therefore ye oyle FC shall make an Equilibrium with ye water HG, now it is neces= =sary to make ye whole remain in that estate that ye points H and F should be equally pressed according to ye principall above: therefore ye quantity of oyle FC shall weigh as much upon F as ye water HG upon H, for some thing happens to mercury and water; for if we put in ye Syphon ABC mercury to ye height DE and powr gently water through ye inclining ye syphon ~~the mer=~~ =cury a little at ye beginning to ye end that the water may not mix with ye mercury, and that ye water may be elevated into C and ye mercury into I, ye water will descend to ye Horizontal line KL and then ye water KC with ye mercury KB, shall make an Equilibrium with ye mer= =cury BI; and as ye specific gravity of ye mer= =cury is to that of ye water, so reciprocally ye height LI and by that means it will be easy to determin the specific weight of Liquors in regard one of another, for if ye mercury be 14 times as heavy as water, KC shall be 14 times as great as LI.



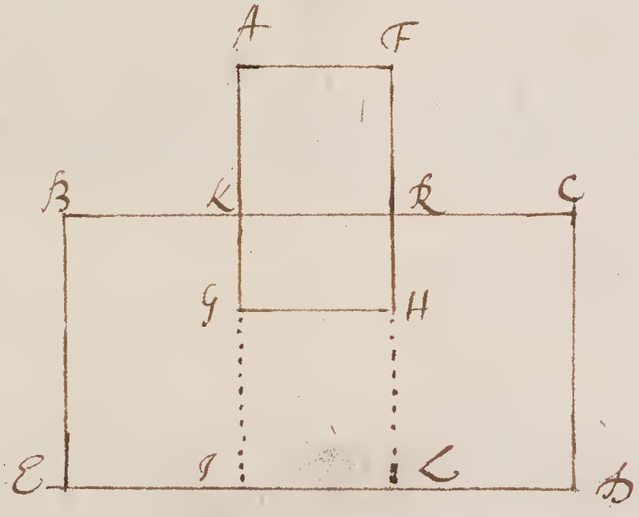
Having considered ye Equilibrium of Liquors one with another we may consider that of firm bodyes wch swim upon ye water, as wood, wax, &c see ye rules

Rules for ye Equilibrium of firm bodys whose Specific wright is Less than that of water.

RULE I

Having firm body weighing more than ye aire and lighter than water lime put upon water with a little sink and elevate ye water, and all ye sink part shall be to ye wght as its specific wright to that of ye water.

Let there be in ye figure following Bc BE water whose upper surface Let be BC, contained in some vessel, and Let AF GH be a cubic body Specifically lighter than ye water, and heavier than ye aire; I say that it will not remain upon ye surface of ye water;



for ye femane column of water KR JL would be more pressed than an equal column BE JK, since ye wright of ye body AH would be more there, therefore ye wright shall descend and enter into ye water, but shall not entirely hid, because that ye column KR-JL com= =posed of that body and ye water would be lighter then an equal column of water BE JK; Let it therefore sink to KR, and let ye water that environs it be elevated to BC, wch shall be higher than it was before because that ye portion of ye body KG HR possesseth ye place of one part wch is obliged to be elevated: I say that ye water contained in KG HR, whose place ye body occupys, shall of an equal wright to ye wright of ye whole body, that is to say that it a quantity of water equal bulk to KG HR weighs as much in ye aire as ye entire body AF GH, it will remain in that situation; and that part of ye body viz KR GH shall be to ye whole as ye specific wright of that whole body shall be to ye of ye water.

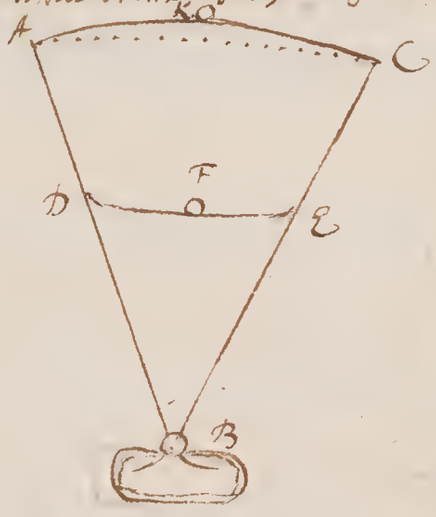
So if ye body AF GH is to ye water in specific wright as 3 to 4, ye part AF KR wch shall plus below ye water shall be ye 4th part of its whole height; for if it would weigh 12 pound in ye aire, as much water would weigh 16 pound and by consequence ye part KR GH would weigh 12 pound if it was water, it shall ~~be~~ weigh therefore but 9 pounds cause ye ~~space~~ part above ye water AF KR shall be three pound and ye whole shall weigh 12 pounds as ye space of water occupied by ye part of ye wright wch enters there, wch shall be 16 pound in ye same proportion as 3 to 4. and by ye first rule ye wright shall

remain in that estate in ye water. and because that cork is 4 times lighter than water B c E b a cylinder of cork # F G H, it will descend, and if ye superficies of ye water is double to ye of ye base of ye cylinder, ye water will not be elevated but to ye eight part of ye height of ye cylinder, and ye cylinder shall not descend into ye water but $\frac{1}{4}$ ~~of~~ so that ye part wch remains out of ye water shall be $\frac{3}{4}$ of ye whole cylinder.

The water some times if left to light bodys, and is elevated a little concave= =ly against ye part above K, and sometimes it make a little sinking below as hath been explained above wch may make some difficulty; but ye little water wch is elevated about ye right of ye sur= =face of ye water will make there but little alteration, and we do not consider it.

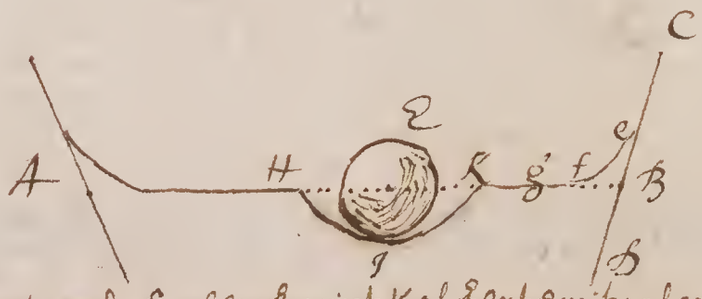
That property of ye water to stick or not to stick to certain bodys, makes appear= =ance sometimes surprising effects. See ye examples.

A B C is a glass half full of water whose upper surface is b E: if there is small bubble of broth full of air, as F, or a small hollow ball of glass full of air lighter than ye water or some other of like body, it will go towards ye edges E or b, and will keep there as it elsewhere; but on the contrary if ye glass is full of water as A C then ye small ball K shall not approach ye sides but it pushed will return towards ye middle in but there are other small light bodys wch make contrary effects.



Take a small ball of wax not wet, and place it gently upon ye water in F when ye glass is not full it will fly ye sides, and if you put it in K towards the midle when ye glass is full it will go hastily tow= =ards c until it touch ye side of ye glass. these eff= =ects may be explained in this manner.

A B is ye surface of ye water when ye glass is not full, c D is ye side of ye glass where ye water makes a small elevation as E f g, E is ye ball of wax wch being slimy and pla= =ced gently upon ye water makes there a small hole # J K because that ye water doth not stick to it, and ye ball enters below ye face of ye water # H K B until that part wch is below with ye air wch is comprised below ye horizontal pointed line weighs as much as ye water wch contained. there in ye space comprised by that pricked line # K and ye crooked line # J K, now



if we advance ye ball towards g, when ye point K of ye extremity of concavity # J K is seen to approach somewhat nearer ye side of ye glass than ye point g then ye water which is in E f bring no more sustained by that which is at ye point g descends, and mounts to ye point g the curve E f g remaining in its first estate.

But if that glass is quite full and that ye water passeth above ye brim with owl running over as may easily be done, and as is seen in ye following figure where ye water makes a concavity from L to ye side of ye glass B, then when ye bowl E shall be advan=ced unto ye section H J K it encounters ye concavity L B, as in P, that point P shall be lower

Fig I

than ye point H of ye other side of ye bowl E, and by that means ye ball shall be found in a steep place wch shall be yet ye greater when ye same section shall approach nearer unto B, and that steepness shall be more still when ye ball toucheth ye glass at ye point B, as is seen in ye same figure from ye other side of ye glass.

For ye same reasons when ye two of these balls are put some what near one ye other they joyn: for Let ye Line A c b E F B be ye Level of ye surface of ye water, (a (F) b e b F ye two holes wch ye balls make, and ye point e ye intersection of ye holes, it is evi=dent that ye point e will be lower than ye Level of ye water A C F B, and by consequence will

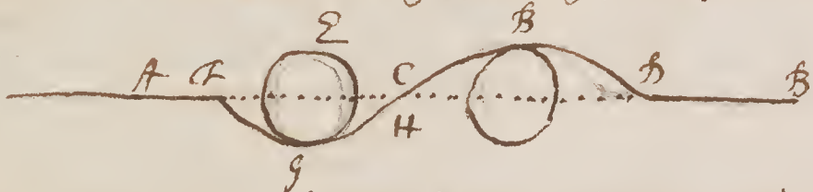


Fig III

have a descent one both sides; wch makes ye balls run till they meet one ye other as may be seen in that same figure. but if one of ye balls is wet so that ye water sticks to it, they will push back one ye other; wch is prevented after ye same manner; for in ye wet ball B in ye following figure, there is made and Elevation of water as c B and B b, and ye other a hole as F g H and it

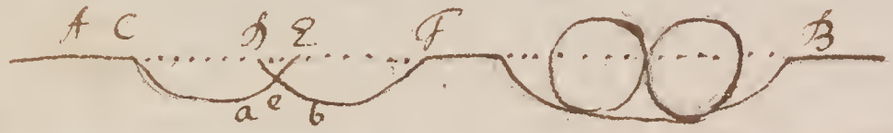


Fig II

we push ye one towards ~~the other~~ ye other, ye water shall be elevated more towards C between ye two balls and in greater quantity wch shall make ye balls be pushed back one from ye other.

But if ye two balls in ye precedent figure are moistened they will approach one ye other, because of ye concavity wch remains between them, and will joyn by ye same cause as two

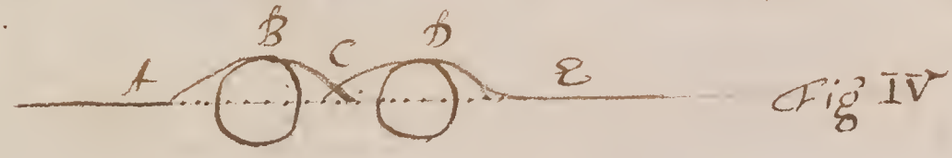
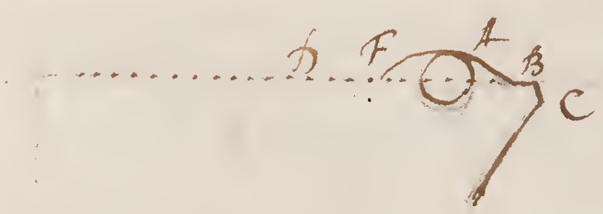


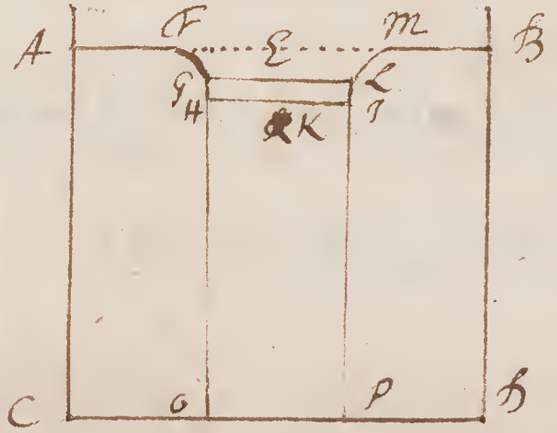
Fig IV

drops of water joyn together and make but one drop. two Elevations of ye water B C, c B in ye following figure, are as two half drops wch ought to joyn together in their touching parts so Lillie

It is ꝺ same reason that two wet balls ioyn together and that they approach ꝺ sides of ꝺ glass when it is not full: for there is made a like elevation of ꝺ water. and when it is full and that ꝺ water passeth higher than ꝺ sides ꝺ wet ball is pushed back after ꝺ same manner as ꝺ a ball not wet; for approaching ꝺ side of ꝺ glass C, ꝺ small elevation of ꝺ water AB, elevates that wch is between B and C, and than all the elevation is more than that alone BF wch is but concave, and by consequence ꝺ bowl shall be pushed back from ꝺ side to b, wch is conformable to experience.



The difficulty that water has to ioyn to wax, causes that sometimes bodys heavier than water, do not run to ꝺ bottom as ꝺ small cylinder EK is of box or of some other wood heavier than water and that it is rubbed every with tallow or varnished to hinder ꝺ water from sticking to it, it will remain suspended and sink into ꝺ water as FGHKJLM; for ꝺ space of ꝺ air GFLM, wch is below ꝺ level AFMB having no weight, ꝺ bottom OP shall not be more charged than CO wch is equall to it, and also we may push a little lower ꝺ small cylinder with one finger, with only it going to ꝺ bottom; provided that ꝺ curve FG, MJ may be less than one line and a half, for they may be two lines without making ꝺ thin upon GE, it will have more air on ꝺ tops, and as soon as we shall take away the finger, ꝺ cylinder will ascend, not because ꝺ air withdraws from it, but because ꝺ side columns of water whose bases are equall to PO, which move and make ꝺ cylinder GE to mount. one may put from ꝺ same reasons a small quille upon ꝺ water when it is calm without sinking, if it is a little slippy and dry; but as soon as it shall be wet, ꝺ water will stick to it, and it will sink to ꝺ bottom.

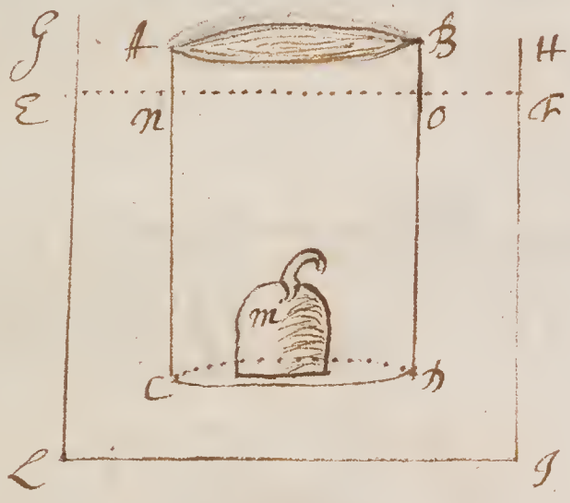


One may be surprised that ice swims on ꝺ top of ꝺ water, for it seems that being colder than running water it should be more condensed and by consequence heavier. but we must observe that ꝺ ice is allways mixed with some bubbles of air, as hath been explained in ꝺ twenty part; and it is that mixture wch renders it lighter; and although that in some places of ꝺ ice; that mixture is not visible because of ꝺ smallness of ꝺ pores cells of ꝺ air; we may believe that there is always a little, and that little joyned to ꝺ ice whose condensation in ꝺ water is not very considerable, may make a compositum less heavy than ꝺ water:

The same thing happens to lead, to grease, wax, and to some other such matters; for these matters being melted sustain those parts which are not yet melted, which proceeds from hence that there is allways made some void intervalls between ꝺ parts of these bodys when they begin to harden. If we break a ball of lead in ꝺ middle we shall find towards ꝺ center a considerable void place; grease in its congealing becomes opaque because of ꝺ small void intervalls wch are there made, which hinders ꝺ light to continue in a streight line by ꝺ diverse refractions and reflections which it suffers.

Application of ye Last Rule

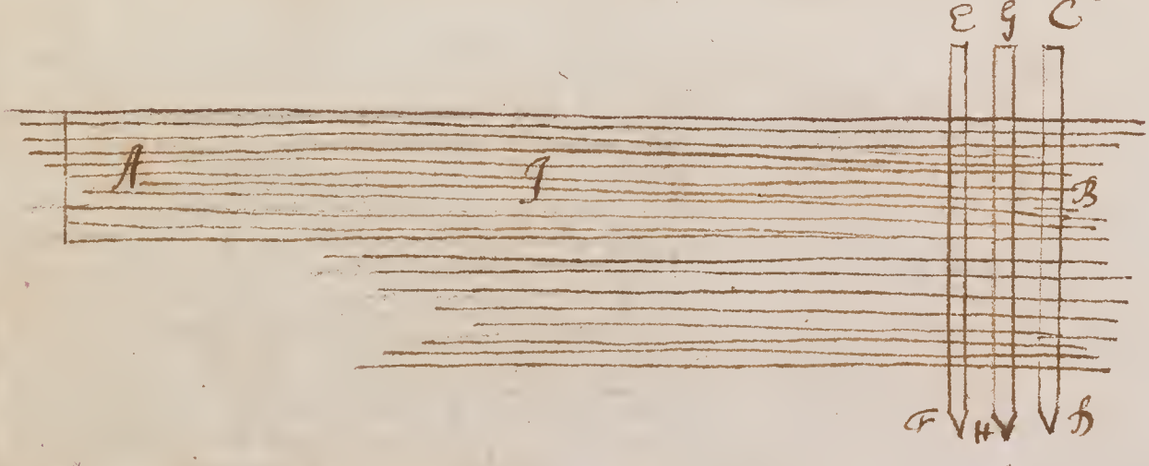
If there is fastened an empty vessel A B c b in ye water E F I L contained in some vessel, holding ye empty vessel so that it may be upright, and may not be overturned; there needs as much force to keep one part stopped at a certain depth below



the surface of ye water E F as that wch is necessary to sustain in ye air a weight m wch being put in the bottom of ye vessel A B c b may keep it in that situation, wch weight with that of ye empty vessel ought to be equal to ye weight of ye water wch should possess ye space n o b c, as hath been explained above:

We may apply that effect to ye ice wch is formed in rivers round about ye piles wch sustain bridges, to judge that if ye rivers rise, ye ice wch is joyned to ye piles may lift them up and overturn ye bridge. For supposing that ye ice is a foot thick, and that it weighs with the air wherewith it is filled less by ⅛ than ye water, we may easily calculate to know what weight may hinder its elevation to ye top of ye water, as if it is 400 feet in surface, it shall be 400 cubic feet each of wch ~~a cubic foot of water~~ shall weigh but 64 pounds instead of 70 for a cubic foot of water, and ye product of 6 ye difference of 64 and 70 being multiplyed by 400 is 2400 pound: now if ye weight of ye piles of ye bridge is greater than 2400, ye ice shall not carry away ye piles; for there is yet more resistance that ye piles make by their bearing against ye firm earth where they are engaged, as to be wonder'd:

If there is no ice but from ye side upward, and it is extream long as A B, it may



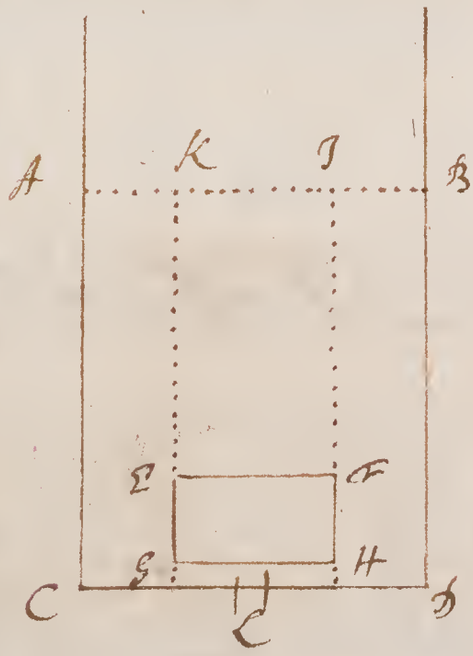
serve as a lever, as is seen in ye foregoing figure, by making its support upon ye last pile c b

to woot up ye piles E F and G H; but it ought to take ye proportion of its force but from half the distance A B because that part of ye Ice A B acts not but according to its distance from ye point of support B but if there is as much Ice at ye other side and of ye same length then it will empty its whole effort: but as ordinarily ye bridges are very heavy they are for ye most part carryed away by ye continual shoc of great pieces of Ice, wch by little and little shake them and woot them out by knocking against them, than by ye Lifting up of ye Ice wch cannot there make a great effort.

If a light body is put into Liquors of different specific weight, ye part sunk in ye one shall be to ye part sunck in ye other as ye specific weight of one is to ye specific weight of ye other. Now ye same reason ships and boats Loaden with merchandise ought to sink into ye water till ye water whose place they possess below ye level, weighs as much as ye vessel and all that wch is in it; whence it happens sometimes that these vessels putting from ye sea into rivers unto ye bottom. because that ye fresh water being Lighter than that of ye sea, ye space of ye fresh water equal to that of wch ye whole vessel should occupy is less heavy than ye weight of ye vessel, and that in ye sea ye weight of ye vessel is less heavy.

Rule II

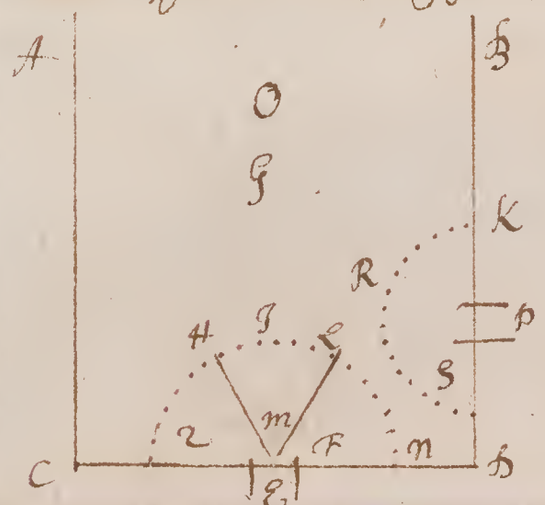
Bodys Lighter than ye water being retained by force at ye bottom of ye water, and being afterwards set at Liberty are Elevated to ye top of ye water in ye following manner:



A B C D is water contained in ye vessel; E F G H is a body whose specific weight is less than that of ye water; now ye Column K F G H weighs less than a Column of water of ye same bignes A H B D and by consequence ye water near ye point H, between H and D is more charged than that wch is between G and H, and by consequence it will sink and run under ye body G H and will push it up. ye other parts of ye water wch are at ye bottom at ye same depth as ye bottom of ye body have ye like effect to push it up; and as it will meet with heights of same dispositions it shall be allway Elevated till one part be above ye water; and because it is Elevated with swiftness it shall pass a little higher than ye place where it ought to stop; but it will descend a little Lower than that place and at Last after some other balancings it will be stopped in ye place of its equilibrium according to ye foregoing rules.

But if there is a hole in ye bottom of ye vessel as L thro wch ye water may run ye body E F G H shall not be Elevated, for ye same water wch ought to push ye body on high descends by ye hole and is drawn from ye side by its viscosity; and being pressed by ye upper part of ye column of water K E I F, it will remain always at ye bottom of ye water, till it is wholly run out.

It is evident by what is said above that if A B C D is a vessel full of water having an hole in E, ye water wch is at ye side as in F being pressed by ye whole superiour water, shall be pressed towards ye hole with more force than that wch is above perpendicularly; as in I if ye point G is farther distant from ye point E than ye point F; we may see ye experiment in permitting to fall a small peice of paper twisted and wet, or some other small body a Little heavier than ye water as ye fragments of ye sawings of horns: for as soon as ye fingers is taken away wch should sustain ye water in E, ye water running shall follow ye paper in F wch will make to know ye parts of ye water near to ye small body; are thus pushed after ye same manner as ye other parts wch are near ye hole, and wch are comprised in ye Hemisphere Q H I L N, those wch should be nearest as in O or F will go to succeed those wch run swiftest than ye farther distant, as H or L and much more than those wch are as in G or K highest as in O we may make an experiment by permitting small parcells of some matter to fall into



ye water before ye fingers is taken away. for we shall see that those wch are at or L, and wch should

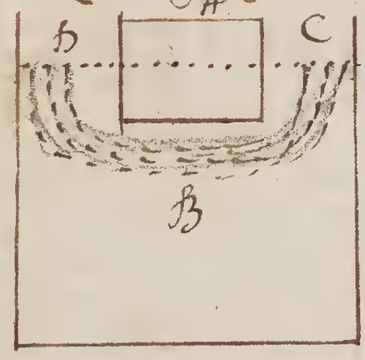
tall perpendicularly, will be determined to go by ye readius of ye Hemisphere H E and L E with greater hastiness than ye like small bodies wch should be in o ov m e. the same thing will happen if ye hole is in P instead of E: for ye small bodies wch should be in ye Hemisphere K R S, runn there as soon as ye finger is taken away: it is for this reason that if we stick a quill or wire a finger about ye centre, and that ye hole is sufficiently great; ye parts of ye ground, wch are near mount to pass there and do render ye wine troubled: when ye holes E ov P are very small, ye Hemisphere doth not extend so far as when they are great.

Rule III

Bodys whose specific weight is greater than that of water, fall to ye bottom.

Explication.

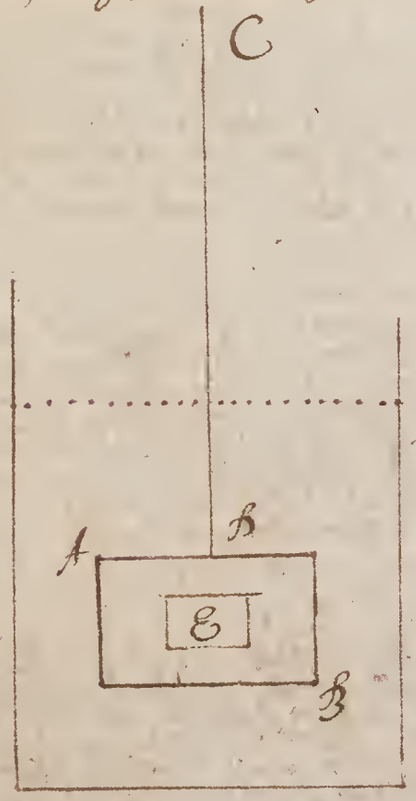
Let A be ye body heavier than ye water, will descend after ye same manner in ye water as in ye air if it doth not descend less swift, ye water B wch shall immediately below shall be pushed down by that body which striking ye other lower shall push it to ye side towards C and D in ye circumference and ye whole water of this vessell shall be put into motion; and when ye body is descended as in B it shall make other new billions to fill that place it shall quit till it toucheth ye bottom.



Rule IV

Bodys whose specific weight is greater than that of water, loose in ye water as much of their weight as is ye water whose place they occupy.

long ye body A B, in ye water by ye cord C D; suppose ye part E was entirely taken away so ye rest weighs as much as ye water wch should fill ye space A B if that body was taken away, it is evident that it will then make an equilibrium with as water situated at ye side; and by consequence will not push upon ye cord C D, no more than if we had dipt it in ye water without ye body: therefore if we suppose that ye part E is added to it, ye whole body shall not weigh upon C D but so much as ye part E; whence follows what has been proposed: from hence we may find a means to examin ye specific weight all those bodys wch weigh more than ye water, both in respect of ye water and of other bodys; for example Let ye body A B be of gold, it is necessary to weigh it in ye water with a balance, they sign to one of ye scales by a cord and put an equall weight in ye other scale, they after wards dip it entirely in ye water, and it $\frac{1}{20}$ of ye weight wch made an equilibrium in ye air must be taken away to continue that equilibrium when it is in ye water we may know that ye specific weight of ye gold is to that of water as 19 to 1, and if ye body is of Lead and that we must take away $\frac{1}{11}$ of ye weight that it may make an equilibrium in ye water; we may know that ye specific weight of water in regard of Lead is as one to 11 and thence that that of gold in regard of Lead is as 19 is to 11; whence we may know if a piece of gold falsified without alteration; for in a like experiment it looses in ye water $\frac{1}{20}$ ov $\frac{1}{12}$ of its weight we may judge that it hath other metals mixed with in a sufficiently great quantity, as $\frac{1}{3}$ ov $\frac{1}{2}$ and that it is falsified but if looses but $\frac{1}{19}$ little mixture. but it we suspend in a vessell with a cord a great cylindric body of glass ov metal so that it allmost fills it without touching ye sides ov ye bottom, and we pour water to fill up ye void places to ye height of ye cylindric body; then ye wch could



easily support ye vessel before ye water was put in; shall be at some trouble to support it, for it shall weigh as much as if it had been filled to ye height of that body after it had been filled to ye height of that body after it had been taken away; and he who sustains ye vessel shall be discharged of so much of so much of his weight as is ye weight of ye water whose place ye cylindric body occupys; ye reason is that then that body ought to follow ye same rules as ye bodys wch are sustained in ye water whose weight is diminished by ye weight of a like volumn of water as that it occupys and by consequence he that sustains ye vessel ought to perceive himself discharged of a weight of water equal in bulk to ye cylindric body and ye other wch has his hand under ye vessel, besides ye weight of ye vessel ought to sustain as much weight as that of wch ye other ought to be discharged, and also that little water wch had been poured in.

Sometimes bodys lighter than water go to ye bottom by a cause sufficiently easy to explain; see an experiment: take a cylindric glass of 7 or 8 inchs high and of three or four lines large as A B C D wch hath an hole E at ye middle of ye bottom of about 3 lines large fill ye vessel holding a finger under E, and put on ye top of ye water a small ball of wax wch may pass through ye hole E and when ye water shall be calm and stopped take away the finger and let ye water run; ye wax will descend after ye same manner as ye surface of ye water and will pass thro E with ye last water: but if you give a great circular motion to ye water, let it be by turning it cross ways against the sides of ye glass or otherwise, when you shall take away ye finger from ye hole you will see ye ball stop with ye first beginning of ye water had begun to turn, and make a void place in ye middle of ye water where ye air is insinuated as from H to E, and that void place is not filled up till ye whole water is run out, and we may always see a column of breathed air from ye top of ye water to ye hole E.

This effect is explained in this manner ye water wch is in ye semicircle C I m D is pushed towards E, when ye water is calm and without any considerable motion, as hath been proved, and it succeeds to that wch goes out before that wch is in H is descended there; but when ye water hath a great circular motion ye parts tend towards now & now & cannot arrive towards E before ye turnings round, and also they are carried towards ye sides of ye glass because they are pushed according to ye tangents of ye circles that they describe; whence it follows that ye entire column F E shall forth with and passe thro with that little ball of wax that is above it; and because that ye water wch is at ye side of that column wch is run throw, cannot fill up its place so swift, because of its circular motion wch has not that direction, it is necessary that ye superior air insinuate there by its weight and its spring, and remain there till all is run out:

It happens sometimes that ye small ball is not directly upon ye column, and then it is carried a little aside between ye two waters; and also if it returns towards ye middle, ye column of air pushes it back towards ye sides of ye glass by its spring: but at last it enters in ye void column and passes afterwards thro ye hole turning very swift before half ye water is run out:

It is for ye same reason that if there is a great hole in ye bottom of a deep water as in a river or in sea, where ye water runs towards places a great distance off as it is said that ye Euripus sea runs into ye Euxin ye water drawn with it ye vessels wch pass near ye whirl pool; for ye water taking after that manner takes always a circular motion and produces ye same effects in regard of ye vessels wch pass over it, as ye water turning round in ye glass A B C D in respect of ye ball of wax. It is said also that there is in some seas near to Scotland a like turning round of ye water where vessels are overturned, and that there is seen sometimes a breach in a place of ye neighbouring sea wch is low. It is easy to judge that ye water takes up more time to run thro ye hole E when it turns round than when it doth not since in ye first case ye air occupies one part of that hole.

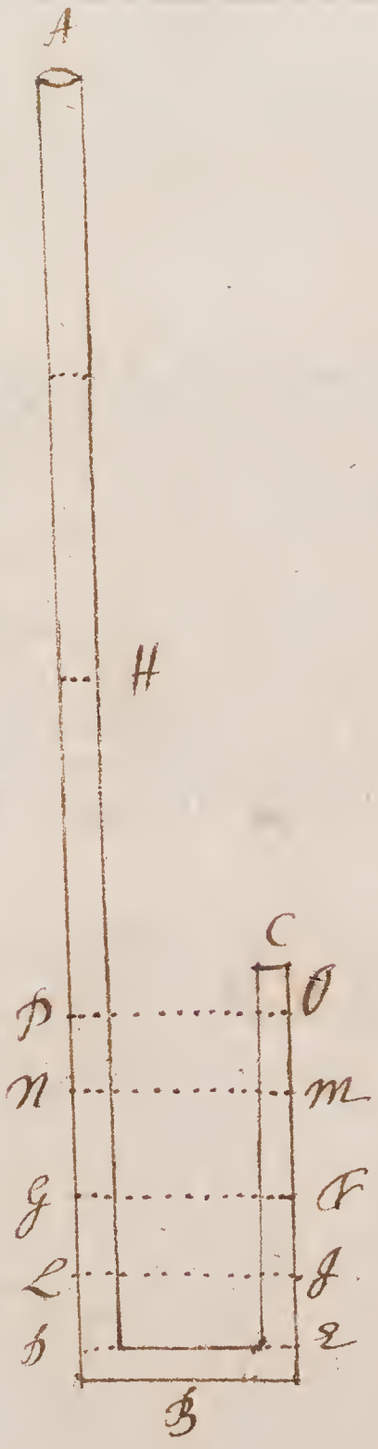
Discours II

Of the Equilibrium of Fluid Bodies by the Spring.

The Air and flame act by their spring to make an equilibrium with other bodys the spring of the air is manifest by many experiments as in the Barometre where it is much dilated, and in the wind gunns where it is extreamly contracted; but it is very difficult to explain well the effect dilations and condensations. how to give some idea we may consider the whole extent of the air from the top to the bottom as a great heap of sponges or balls of cotton wherof the highest have their naturall extent. but the lowest being pressed by the weight of the upper are reduced into a very small thickness and that they regain their first dilatation, when they are discharged of the weight of the other. according to the hypothesis we may say that the air at the bottom makes an equilibrium by its spring with the weight of all the rest of the air whereby it is charged; so that if that superiour air becomes heavier or more of it, the inferiour air is a little more condensed; and if the upper becomes less heavy or if it is of a less extent, the inferiour is more dilated. we may compare the spring of the air, to the spring (d'acier steel) of wooll wch is pressed and is more contracted when it is charged with a greater weight, and wch is elevated and extended when one part of the weight is taken away; as we may say that the spring of the (steel) wooll being pressed and reduced to a certain figure by a weight, makes an equilibrium with that weight, we may say likewise that the lowest air condensed as it is makes an equilibrium by the spring with all the weight of the Atmosphere.

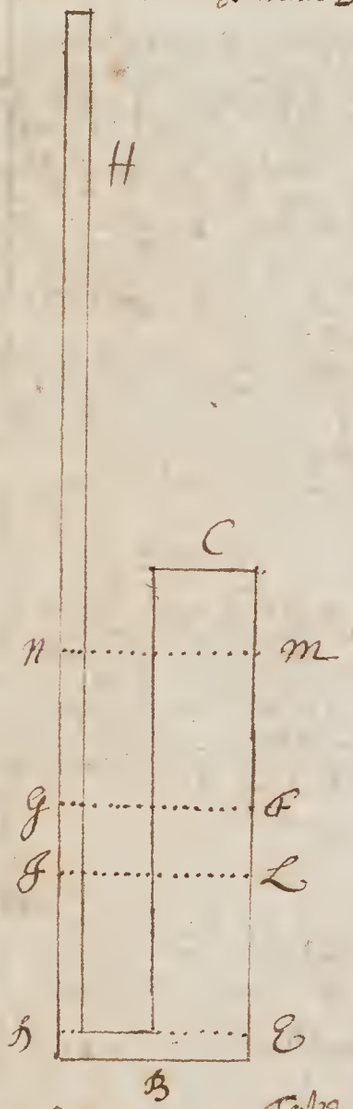
We see by many experiments that the condensation of the air is made according to the proportion of the weights wherewith it is charged. Before we go further. take a crooked pipe of glass A B C stopped at the end C and open at the other; powr into it a little mercury to the horizontal height B E to the end that the inclosed air C E be neither more nor less dilated than that wch is in the other branch. for if the mercury was a little higher in one of the branches than in the other, the air should be there less pressed. It is necessary that E C be of a moderate height as of 12 inches as it is supposed in that figure and of the other B A as great as you please. the mercury being therefore on both sides at the same height towards B and E and the air E C having no communication with that of B A powr by the end A with a small funnell of glass new mercury; taking heed that no air enters into the space C E, you will observe that the mercury will mount little by little and little towards C, and will condence the air wch was in C E, and that if E F is six inches F G being an horizontal line, the mercury shall be mounted in the other branch to H if that point is distant 28 inches from the point G, and that the Barometre would be then at the height of 28 inches in the place of the observation; for if they were but at 27½ then G H would be but 27½: now in that estate the air in C F C is pressed by the weight of the Atmosphere wch is supposed equal to that of 28 inches wch are in the space G H; and by consequence is charged with a weight double to that wherewith the air is charged wch is in the place where the experiment is made, and wch is like to that wch was in E C before it was condensed with the weight of the mercury G H: It is therefore manifestly seen in that experiment that the air E C will follow the proportion of the weights we may find the same proposition in the other experiments by making the calculation in this sort; we must take for the first terme the summ of the weights of the Atmosphere and of the mercury wch shall be mounted higher than the bottom of the air in the branch E C. for the second terme, the weight of the Atmosphere that is to say 28 inches of mercury; for the third, the distance E C and the fourth proportionall shall be the space or height where the inclosed air shall be reduced in the pipe E C: as if the air was reduced only to the space I C of 8 inches, we shall find that the mercury shall be in the other pipe only fourteen inches higher than the Horizontall Line I L. now these fourteen inches with the 28 of the Atmosphere are 42, we may therefore say according to that rule as 42 inches is to 28 inches so the extent

44



of ye aire EC is to ye extent of C. But if we would reduce ye same aire into ye space mc of 3 inches wch is ye fourth of EC; we must put 84 inches of mercury into ye branch bA above ye Horizontal Line m n, and we shall find that proportion by ye following calculation: as m C 3 inches is to m E 9 inches, so 28 inches ye weight of ye Atmosphere, is to 84 now by changing 84 shall be to 25 as 9 is to 3, and compounding 84 more 28 that is one 12 shall be to 28 as 9 more 3 EC 12 to 3, and if we would know what height of ye pipe it is necessary to reduce that aire into ye space OC of one inch, we must say as OC one inch is to QE 11 inches, so 28 inches of mercury ye weight of ye Atmosphere to 308 and 308 shall be there vertical height wch must be given to ye Mercury above ye point O or P by wch is known that ye branch bA must be higher than 308 inches, that is that it must be about 320 to ye end that there may remain a place above ye mercury to hinder its running out.

The same thing will happen if ye branch EC is much more Longe or much more Less than BA: for if you powr mrcury till it mounts to ye heighth GF, GH ye height of ye mrcury in ye other pipe shall be 29 inches: for as ye mrcury DG makes an Equilibrium with ye mrcury EF, although in a greater quantity as hath been proved above in reference to water, so ye spring of ye air in FC will make an Equilibrium with ye mrcury GH since it would sustain it if GH were of ye same Largeness as FC and by consequence it makes ye like effect as if ye branch EC was as high as ye other end H: it was mrcury to ye same height as H: I have made ye following experiments. having powred Mrcury to such wch was the 3d of EC it was found 14 inches — ½ from above ye L in ye other branch, and it will be found 27 inches and ½ above GF when ye space ECF is half of EC was full, and having raised it to 44½ inches above nm; mC EC contains 15; wch makes always ye same proportion; for ye Barometer gave then at 29 inches and ½: for Like reasons if ye branch EC was much straighter than ye other, ye air inclosed there would make a Like Equilibrium by its spring with ye mrcury of ye other branch. we shall see ye same proportion when ye air shall be more rarified then that of ye place where ye experiments is made; wch will be proved after this manner.



Take a Barometer AB of what bigness you please, as for example of 38 inches, make a mark at a point as Z, at an inche above ye open end B, to wch end that that end being plunged in ye mrcury of ye small vessel CBE unto that mark, there may remain 37 inches above. Fill ye pipe with mrcury and leave there 9 inches of air, to ye end that when ye pipe shall be inverted as may seen in ye figure and sustained with ye fingers, there may be 9 inches of air at ye top of ye pipe; then if you dip ye fingers with ye end of ye pipe in ye mrcury of ye Little vessel and afterwards take away ye fingers, ye mrcury will descend and will stop after some ballancings at 21 inches, wch ought to happen to ye same of proportion of ye weights and condensation explained above, and it may be proved in this manner.

Demonstration

= ure A B of what I call the pipe A B be 38 inches Z B one inch; A H the inclosed aire above the mercu=
= ry that if the finger is taken away the mercury will descend; for as much as aire A H is condensed
after the manner as that out of the place where the experiment is made, it ought to make
~~by the experiment is made~~
by its spring an equilibrium with the whole weight of the Atmo=
= sphere, as hath been proved and being joyned with it with
weight of the mercury in Z H, these two powers together would
surpass the weight of the Atmosphere and it is necessary that
the aire A H dilate it self and that one part of the mercury descend;
but it will not descend entirely descend or aire A H would be
dilated verie much, and in that estate it could not make an
equilibrium with the weight of the Atmosphere: whence it follows
that one part of the mercury ought to remain in the pipe. I
say therefore that if A H is 8 inches it will be dilated and will
push back the mercury so that it will remain elevated 16 inches
above the upper surface of the mercury at Z G Let that Elevation
be Z L. Now there will then be an equilibrium between the weight
of the whole column of aire of the Atmosphere and the spring of the dilated
aire A L joyned to the weight of 16 inches of mercury Z L; and because
the compliment of 16 to 28 is 12, the dilated aire A L shall make an equi=
= librium by its spring to the weight of 12 inches of mercury which
remain for the weight of the Atmosphere beyond the 16 inches; but
as 28 to 12 so A L of 21 inches is to 9; whence it follows that
the mercury ought to remain at 16 inches high above the mark
Z, when we leave 5 inches of aire in the pipe above the mercury
because that the aire is condensed in proportion to the weight where=
= with it is charged. But if the mercury in another experiment
stay at 21 inches, we may judge following the same rule, that
since these 21 inches of mercury make an equilibrium
with $\frac{3}{4}$ of the weight of the aire, the 4th remaining which ought
to have the value of 7 inches, shall be sustained by the spring
of the warmed aire contained in the pipe according to the
distinction of the equilibrium of springs: now 28 inches of
mercury is the entire weight of the Atmosphere is to 7 inches as
16 inches of dilated aire is to 4 inches of aire, wherefore we
may judge that we must leave 4 inches of aire in the pipe
above the mercury, that it may remain at 21 inches
and the aire may be dilated to 16 inches. but if we would reduce
the mercury to 14 inches wch is the half of the weight of the Atmo=
= sphere in the same pipe above the mark Z, we must consider
that there will remain 23 inches to A, and that the dilated
aire at 23 inches ought to make an equilibrium with its spring
to the remaining weight of the Atmosphere. we must therefore say
that as 28 is to 14, the compliment of 14 to 28, so 23 of dilated aire
with the pipe above the 14 inches, is to $11\frac{1}{2}$, whence we know
that we must leave 11 inches and $\frac{1}{2}$ of aire above the mercury in the
pipe before the experiment, and it will manifestly appear that the
spring of the inclosed aire making then an equilibrium but with
half the weight of the aire of the Atmosphere since the 14 inches of mer=
= cury make an equilibrium with the weight it shall be wanting in a double proportion: and by all
these experiments we may judge by observing the same rule explained above, what quantity of
aire we must leave in a great or small pipe that the mercury may stay at what height we please.
Now if the pipe should be only six inches above the mark Z. we shall bring the same proportions in mak=
= ing the same calculation, as for example if 2 inches is the given height of the mercury, and that we had
found that as 28 is to 26 the compliment of 2 to 28, so 4 the space of the dilated aire above the 2
inches of mercury is to $3\frac{5}{7}$; 2 inches $\frac{5}{7}$ shall be the quantity we must leave in the pipe that the mer=
= cury may stop at 2 inches high in a pipe of 7 inches, ~~the~~ plunged one inch into the mercury
of the vessel:

But if the quantity of the inclosed aire in the pipe were given, and we would know
to what height the mercury would remain after the experiment; we may observe an Algebraic cal=
= culation, applyed to the same rules, as have taught in my Essay of Logic, and my treatise of Gravity of the aire.

We shall find ye like equilibrium of ye ring of ye pipes full of water and air, supposing that ye greatest weight of ye atmosphere is equall to ye weight of 31 feet of water, as is found by experience: for ye Barometer being at 27 inches 8 lines, ye Barometer of water was at 31 feet 1 inch; and being at 28 inches 4 lines was at 31 feet 4 inches: and if it had been at 28 inches 7 lines as it sometimes happens ye water would have been at 32 feet. And the pipe is 40 feet and we would reduce ye water to 18 feet, we must put 12 feet of air above ye water; for ye air dilating it self double and possessing 24 feet, shall make an equilibrium by its spring with ye weight of ye atmosphere, and ye 18 feet of water wch remain make an equilibrium with ye other half. It is supposed that one small part of ye pipe being plunged or dipped in ye water, to make ye experiment after ye same manner as that of weighing, there remains 40 feet above

whence is seen manifestly that if we plunge into a deep water an inverted bottle full of air, having weights around its neck sufficient to make it go to ye bottom, when it descends but little and little ye water by little and little enters and mounts up into its neck; and when it shall be descended 32 feet deep in water wch will enter there will reduce ye air to half ye extent wch it had in ye bottle before it was plunged there in wch I have explained more largely in my essay of ye nature of ye air.

we may therefore see ye reason of them wch believe that in a pump; we may make ye water mount to 32 feet by drawing with ye C piston) since according to ye play of ye piston) it cannot be elevated but to a determinate height: now let there be for example a body or pipe of a pump uniform of 20 feet having above ye 20 feet a C piston) of ye same Largeness wch cannot be elevated and depressed (omit ye space of one foot, I say that if there is a C long pape) at ye bottom of ye pump and we play ye C piston) ye water cannot be elevated to 12 feet. Now let it be elevated if it be possible to 11 feet on that the pain upon ye piston) there will remain 9 feet of air to ye C piston) water to elevate 11 feet high and we see pain air wch is required in elevating ye piston) one foot, cannot be wanting, but as and that 9 to 10; and because that 21 ye compliment of 11 feet to 32 wch is ye weight of ye atmosphere is to 32 as 9 to 13 5/7 it is necessary to keep ye water at 11 feet that ye C piston) be elevated to 4 feet 5/7 to make an equilibrium between ye weight of ye atmosphere and ye 9 imprisoned spring of ye inclosed air joyned to ye weight of 11 feet of water, as hath been explained above whence it follows that by elevating ye C piston) one foot only, ye C long pape) will not open and ye water will not mount any higher than 11 feet.

to give ye rules how these elevations of waters in ye pumps we may follow an Algebraic calculation in this manner. we will call x ye height whether ye water ought to mount in ye pipe of ye pump by ye play of ye C piston) calculating ye weight from that C long pape) Let ye pipe of ye pump above ye surface of ye water wch we would elevate be 12 feet, and suppose that we would elevate it to there 12 feet by one only stroke of ye C piston) we shall make this analogy: as 20 ye compliment of 12 feet to 32, is to 32 so is 12 foot of ordinary air, to a fourth proportional that 4th proportional shall be 19 1/5 whence you will see that ye pipe of ye pump must be above 12 feet to make ye water mount to 12 feet by one only stroke of ye piston) but it ye play of ye C piston) was limited to 2 feet, we may say as 32 — A is to 32, so is 12 — A to 4 — A, ye first term is ye compliment of ye unknown height whether ye water will mount, to 32 feet of water wch is ye weight to ye atmosphere, ye third term is ye 12 feet left by that height and ye 4th is ye 2 feet whence ye C piston) is elevated joyned to 12 feet left by ye same height: now ye product of 14 — A by 32 — A is 448 — 46 A + A, and ye product of ye two middle terms is 384 — 32 A, ye equation being reduced there will be an equality between A A and 14 A — 64 and because we cannot take away from 49 ye square of ye half of ye roots, 64 is that mark wch continuing to pump we shall at many times make ye water mount to ye piston) and to know how it will mount at ye first stroke, we must suppose that ye C piston) may be elevated these two feet: there will be therefore one uniform pipe of 14 feet and following that wch hath been said in ye play of Logic and ye tartaize of ye nature of ye air, we shall make this calculation: ye inclosed air was 12 feet + A is to A of 32 to 2 — A, ye equation being reduced we shall find that A A should be equall to 24 — 10 A, and at last that ye value of ye root shall be seen what that of A 1/2 wch taken from 2 there will remain 1 1/2 and taken from 2 there will remain 1/2 a little more taken by consequence ye water will not mount by ye first stroke of ye piston but to 1 foot 3/7 a little more

If it had been supposed that ye play of ye C piston) was one foot, we might know by ye same calculation wherein ye water would be elevated by ye first stroke of ye C piston) and if we would know whether it may be elevated after many strokes, we must say as 32 — A is to 32, so is 12 — A is to 13 — A, ye equation

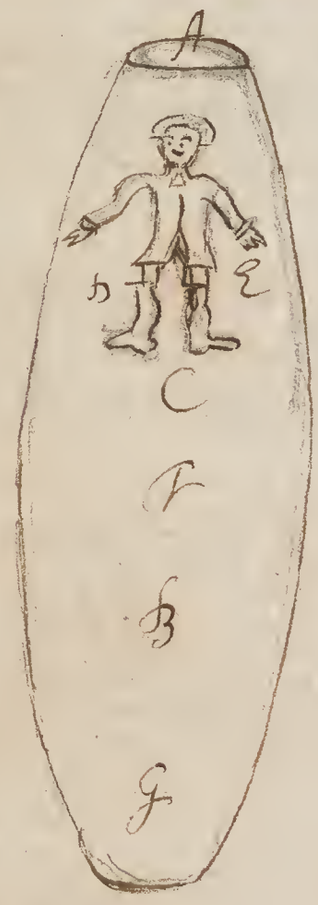
being reduced we shall find 1344 —— 32 = to ## ye squares of 6½ half ye roots is 42¼, from wch taking 32 there remains 10¼, whose root is 3 25/27 a little less take that from 6½, there remains 3 54 ad that to 6½, it shall be 9 27 roots; whence we see that ye water can never mount when ye pipe is void, but to 3 feet and 1 a little more altho we play ye piston as much as we please but if ye pipe had been fixed to 9 feet 18/24 we might conclude that ye water might mount to 12 feet by many strokes of ye (piston) let us suppose now that ye pipe to ye piston may be 14 feet, and that ye play of ye (piston) may be 2 feet; 32 — A shall be to 32 as 14 — A to 16 — A. to find easily ye equation we must multiply 32 by 2 ye difference of 14 and 16: ye product is 64 now ye absolute number and 16 4 shall be ye number of ye roots and A A shall be equall to 16 A —— 64, from wch taking 64 there remains nought, whose root is 0 wch taken away adds to 8, makes allways 8, wch marks that there is but one root and that ye water cannot mount but to 8; but if we play ye (piston) a little higher than these two feet, ye water will mount to 14 feet. the analogy is easy now ye (piston) being mounted to 2 feet ye pipe shall be of 16 feet and ye water being at 8 feet there will remain 8 feet of air; but 32 is to 24 ye compliment of 8 feet to 32 as 8 feet of dilated air to 8 feet of common air: therefore ye water will mount higher than these 8 feet if ye (piston) as played but 2 feet.

whence may be seen that to make ye water mount by application to a conseivable height as to 20 feet, we must diminish ye Largeness of ye pipe of ye pump and give sufficient play to ye (piston) suppose that ye surface of ye piston were 4 times as large as large as ye base of ye pipe one foot of ye Elivation of ye piston would be as much as 4 it is ye (piston) was not Larger: it therefore ye play is ½ foot it shall be ye same as if it was elevated to 6 feet being of ye same Largeness: now ye 4 terms of ye equation being 32 —— A: 32:: 20 — A: 26 — A there will be 6 times 32 viz 192 from one term of ye equation and ye other 26 A it shall be therefore A A equall to 26 A less by 192, ye square of ye half ye roots is 169 less than 192: and by consequent in pumping a long time we shall make ye water mount to 20 feet.

if in ye example above we take 8 feet for ye heighest team of ye water, when ye pipe is 14 feet and ye play of ye (piston) 2 feet, it is easy to prove that if we suppose 2 feet of water upon ye (forepage) it will make an end of mounting a Less weyon of 4 to 7 than of 27 ye compliment of 5 to 32, to 32; and by consequent ye water will mount heighter than these 7 feet. ye proportion shall be allways more inequall in taking 10 feet or 11 feet and if we take 7 feet instead of 8 feet, ye water will yet mount, for there will rest 7 feet of air; now 25 ye compliment of 7 to 32 is to 32 as 7 to 8 24. therefore if ye (piston) goes to 2 feet it will make ye water mount heighter than 7 feet; it will mount also more easily if we pow upon it but to 6 feet: for there will be 8 feet of air: now 26 ye compliment is to 32 as 8 to 9 22 equilibrium ye (piston) goes to 10 feet it will also make ye water mount better than when it was at 7 feet and also better when it shall be at 8 feet &c: if we would know what play of ye (piston) would be necessary to make ye water mount to 30 feet we might take a number a little greater than ye half of 30 as 16 ye compliment is 16 ye rest of ye air is 14, as 16 to 32 so is 14 to 28: it is necessary therefore that ye (piston) be elevated 14 feet, so that it ye pipe is 2 inches diameter than ye (piston) may be 7½ inches, for ye square of 7½ wch is a little more than 14 times 4 ye squares of 2 inches, and then it will suffice that ye play of ye (piston) may be one foot. but as to ye feet ye elevation is yet more difficult, there must be 8 inches of diameter to ye (piston) that its play being one foot it may elevate ye water heighter than these 8 feet. we may easily explain ye ye same force of ye spring of ye air by ye following experiment, wch is sufficiently known:

take a pipe A G stopped below about 12 or 15 Lines Large, but a little streighter towards A that one may exactly stop it with ones finger, fill it with water and put there some small figure of glass or of copper hollow within and pressed as is B with a small hole to put in a pin that ye air and ye water may not dry up, and that its specific weight in respect of ye water may be so proportioned, that it we add a little weight it will go to ye bottom and if we take it away it will swim above as wax. stop ye finger to ye open hole A and press it strongly ye small figure will descend to B or lower and to ye bottom; take away ye finger it will ascend; and it being mounted as in E or C against ye finger on again it will begin to descend. ye cause of these effects is that when ye water is pressed with ye finger we press also ye air wch is in ye figure, and it ye condensed altho we do not condense ye water and by consequence

we make a little water entre into ye figure by ye small hole b, wch makes that ye specifick quan=
=tity is then more than that of water, and it descends: but when we take out of water, and it de=
=scends: but when we take away ye finger, ye inclosed air pusheth back ye water by ye same hole
by vertue of its spring wch is set at liberty and regain=
=ing its dilatation, ye figure with ye water and inclosed
air, regains its first disposition and remounts. but if we
take away ye finger swiftly, a small part of ye air will
go out suddenly with ye water by ye small hole. and
both will make by its shoc against ye water of ye pipe
ye figure. It com=
=eth sometimes that ye figure goeth much air out of ye figure
into that being at ye bottom it cannot remount
altho we have taken away ye fingers, then if it neces=
=sary to plunge ye fingers deep into ye vessel and retain
it so that it exactly fill ye channel, so that no exterior
air can enter in place of ye fingers, and it will happen that
ye air of ye figure being then much less pressed dilates it
self more than ordinarily, and makes more weight to go out
of ye figure and ye inclosed air is so to set precautions to ye spe=
=cifick weight of ye water that by putting ye fingers in ye
figure it descend into it and by elevating ye fingers it will
remount; but if we make it descend unto B and take away
ye fingers, it finisheth its descent; wch proceeds from hence
ye weight of ye water A C both not press enough ye air of
ye small figure to make sufficient water enter to augmen=
=ye specifick weight equall to that of water, and that ye
weight of ye water A B presses sufficiently to cause effect
wch makes it descend to ye bottom where ye weight of ye
water being yet greater, condenses ye air of ye small fi=
=gure more than before, and makes a little more water
enter: whence it happens that we have more trouble to
make it remount, where may be seen ye reason of those
wch believe that ye water and ye air do not weigh upon
ye bodys ye bodys wch are below, and they judge so because
we do not feel ye weight of ye air; but we must consider
that our bodys is disposed naturally for such a pressure of
ye air as it is below, and therefore do not perceive any
incommodity. but if we were transported into an air
more than 32 foot heavier, ye internal matter wch should be in our blood and in ye other parts of
our bodys wch are very hot, would attenuate into air and would cause bubbling out wch would
puff up our body and we should be very uneasy. we see an experiment when we inclose a
bird in ye wind pump, how when ye air is reduced to a double or triple dilatation to that wch
it was ye bird dies in a short time because that its blood being no more pressed by
ye cubicaly spring of ye air, casts out quantity of bubbles like hot water when inclosed in ye same
time: but if on ye contrary we were in an air vastly condensed, we might suffer much altho ye air were
at some trouble to descend its pressure; because if on one side it should press or thrust to hinder
respiration on ye other side ye air wch should enter there by respiration leaving a spring would
hinder ye action of ye exterior air: whence it follows that those wch go 7 or 8 foot under water
ought not to perceive any sensible weight, because they are equally pressed on all sides, and
that ye weight of ye atmosphere being equall to ye weight of 32 foot of water, those 8 foot added
do not augment ye pressure but about $\frac{1}{4}$ wch cannot be very sensible. some object against these
reasons and these effects of ye spring of ye air, that when a pipe is stretched at both ends to make
ye experiments of ye inclosed air above ye mercury if we stop ye upper end with
ones fingers to hinder ye communication of ye air with that wch is inclosed, it happens that
when ye experiment is made there seems to him who stops ye upper end, that his fingers is as
it were drawn and sucked by ye mercury wch descends, and also he feels pain like pinching;
whence they conclude that ye distant air in ye pipe doth not make an effort to sustain one
part of ye air of ye atmosphere since it would push against ye fingers and push it back rather than
draw it: to satisfie this difficulty we must consider that when we inclose some body as a wain=
=scot apple in ye wind pump and have pumped out a good part of ye inclosed air, these bodys
puff up and dilate themselves and that if we had inclosed ye half of ones fingers by ye mercu=



of a Cladder cut of by ye two ends or by some other means; that part of ye fingers would be swelled extreamly, and there would be great much pain; whence it follows that part of ye fingers wch stops ye orifice of ye pipe of ye Barometer being contiguous to ye much dilated air and ye weight being pressed by all ye weight of ye Atmosphere, that small part ought to be blown and make a great contrarity towards ye inner part of ye pipe, wch cannot be made without pain, and ye more of air shall be wanted in ye pipe, ye more ideal pushing up and pain shall be sensible, and ye feeble pushing back of that wanted air shall not be sufficient to hinder that pushing up of ye end of ye fingers, since ye weight wch is in ye small air is much more pressed.

It may be objected that when there is 28 inches of mercury supposed in ye pipe if we lift it up without puting it out of ye mercury, ye weight feels of an equal weight to that of ye inclosed mercury wch ought not to happen if it make an equilibrium with ye weight of ye Atmosphere. we may answer to that difficulty by saying that ye hyperion air wch is above ye pipe hath not then any other air to make an equilibrium with; so that wch ought to sustain it at ye bottom of ye pipe, sustains ye mercury wch is there; wherefore it ought to sustain ye whole weight of ye superiour air wch weighs 28 inches of mercury; and if ye pipe were but 15 inches and that ye mercury remained at ye height then we should feel but 14 inches of mercury in weight, because that ye air wch is supported upon ye mercury of ye small bottle would sustain those 15 inches, and would make an effort of 14 inches towards ye top of ye pipe inwardly: so that it would make an equilibrium with half ye weight of ye hyperion air and ye hand would sustain ye rest

The flame can make also an equilibrium by its spring with ye other bodys; but as there is none but ye flame of gun powder wch can reduce to be compressed without being extinguished, and that flame endures but a very small time, it is difficult to make experiments of its equilibrium; and ye force of its spring is so great, that we can not yet find as weight so great that it doth not surmount since it will overturn entire bastions and also mountains.

To understand how it makes so great an effort, we may suppose that there is a certain quantity of Lighted powder wch fills a pipe sufficiently large situated perpendicularly and that a great weight which lightly covers and fills up exactly that of ye pipe in falling, ye flame of ye powder, makes it be contracted till being reduced to a small space there is made an equilibrium between ye weight and ye spring of ye flame without quenching it; wch we may conceive to make during ye space of one second, and in that estate ye spring of ye flame should make an equilibrium with ye weight so that if ye weight was augmented, ye flame would be reduced to a little less space, suffering it doth not extinguish it; and ye spring wch would then be more strong would make yet an equilibrium with that great weight. now if we conceive that in that great weight. now if we conceive that in that moment there is lighted some quantity of new powder, ye spring of ye flame shall be augmented, and ye weight not being able to make an equilibrium shall be pushed on high, and being once in motion ye continuation of ye extention of ye spring of ye flame wch will dilate itself and be extended more and more, will more and more accelerate its motion, and at last will push it very high into ye air.

This being supposed it is easy to conceive that if we put 10 or 12000 of powder in a mine, and that all that powder being lighted may posses a space of 200 feet high and 100 feet large. it will happen that there will be lighted at ye beginning a small quantity wch shall not be sufficient to overthrow ye Bastion: but because that flame hath this property not to be extinguished by being pressed, it shall light 30 or 40 times more than that wch would posses ye chamber of ye mine if it was uncovered; and then its spring is strong enough it will begin to elevate ye earth wch is above such being once in motion and ye rest of ye powder continueth to enflame and fills ye space that ye earth hath quitted in beginning to be elevated, so that its spring may be yet greater than ye weight of ye earth wch is already in motion, it will accelerate its motion more and more and at last blow up ye Bastion or at least one part, till all ye flame hath acquired ye extent wch is native to its fine air:

A little powder produceth ye same effects in cannon; for it is lighted successively (although in a little time) without pushing out ye bullet till ye spring of ye pressed flame surmounts ye resistance of ye bullet; and when it begins to move ye rest of ye powder wch is readily lighted, augments its spring and accelerates ye swiftness of ye bullet till it is pushed to 7 or 800 toises:

whence we may see that a cannon of 20 feet ought to carry ye bullet further than one of 10 feet because that ye powder hath more time to be lighted and augment its spring while ye bullet runs those spaces:

We may see also that if a quantity of powder lighted hath ye force to shake a bullet wch is not well joyned to ye cannon, it shall not pass so far as if it had been well lined and pressed with cork or other things wch may hinder its being put in motion till there is 2 or 3 times that quantity of powder lighted: for in this last case ye beginning of its motion shall be swifter and its acceleration greater.

For ye same reason ye powder being very fine and soft to be enflamed shall push ye bullet further when it is more grosly, because it is more lighted while ye bullet is in ye cannon.

DISCOURS III

of ye equilibrium of fluid bodys by shock

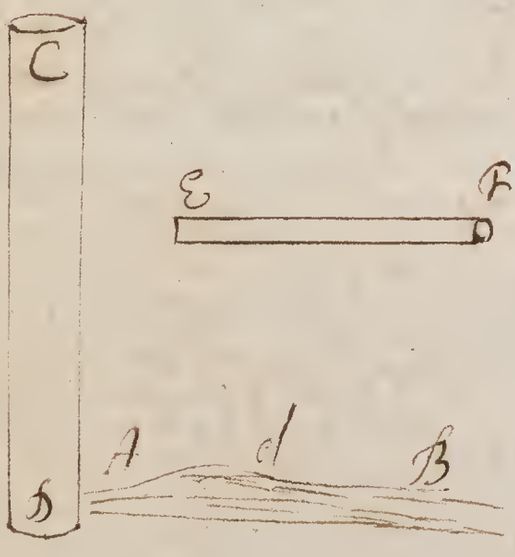
Flame can make an equilibrium by its shock with weights, we may measure its force, if letting it go out of a pipe sufficiently large it dasheth against ye wings of a windmill fitted horizontaly, provided that those wings are situated obliquely in ye same manner as those of wind-mills: in many places ye flame wch mainly upholds the leaves to turn some small engines near it, ye greater ye force by swiftness of motion of ye flame: but that motion cannot be augmented much by art since its force hath not much increased; a flying ball is elevated by ye shock of its flame against ye air, but if it weighs much it cannot be elevated so we may measure its equilibrium. Flame of thunder wch exceeds very swift makes very considerable effects: so it overturns towns and rocks by swiftness of ye flame increaseth also ye force of ye burning, as is often observed in great fires when ye wind is quiet. we see also very considerable effects when ye enamillers blow ye fire of their Lamps against glass or against mettalls to melt them: but because that of flame is not easily elevated to remain of ye same largeness and swiftness, at least it would cost much to maintain it, these engines are rarely made use of; it is not therefore necessary to examine its force in this place now to compare it with that of other fluid bodys:

The air and water are employed in engines to move them by their shock. we may know ye equilibrium that is made between waters and with firm body they dash against by ye following rules:

Rule I

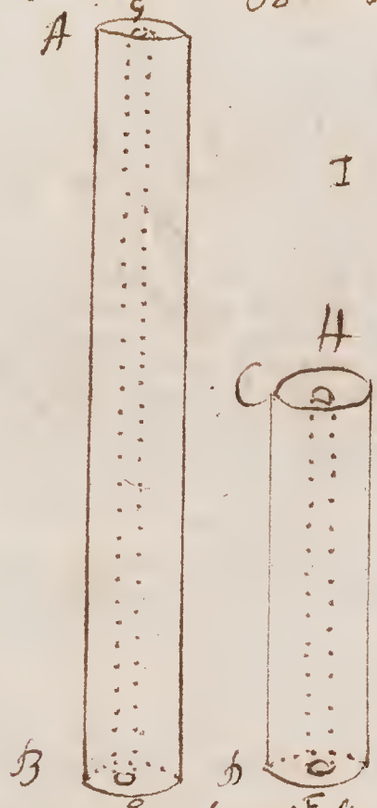
The sprouts of water do not shock by ye effort of all their parts as ye firm body do.

Explication:



A B is a sprout of water going out of ye cylinder C b, and E F is a cylinder of wood; it is manifest that ye parts wch compose E F being linked and united together, make a great effort altogether in dashing against a body by ye extremity of it: so a sprout of water A B being carried according to ye direction A d B, cannot act by its first parts: for ye water being fluid and by it were composed of an infinite number of small geometrical wch glide one upon ye other, as do ye small grains of sand it is but ye first towards B, wch can make ye first effort upon ye body they meet with, and they are as in a hard dash in their turn. towards this if we must consider that ye swiftness that ye water hath at ye going out of a small hole made at ye bottom of a large pipe is very different from ye swiftness of that wch goeth through a pipe of an equal largeness throughout: for as much as in ye last case ye water begins to go out with a very small swiftness and like to that of a cylinder of ice which we permitt to fall:

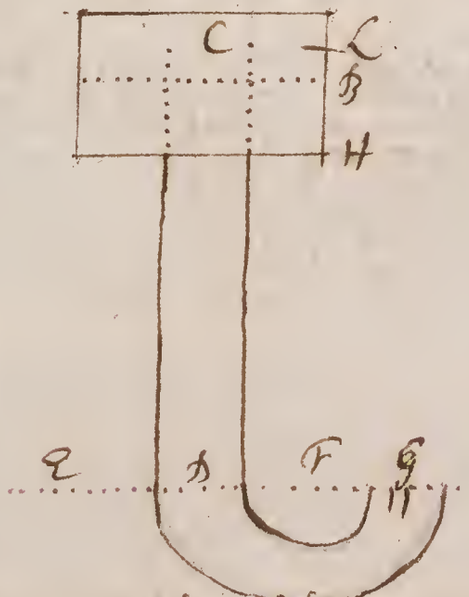
For let a large uniforme pipe AB be full of water held up B with ye fing=
=ger, it is evident that ye same swiftness wch ye water takes to go out is equal to that wch
is in A, and that all ye cylinders of water falls all in
one instice, as if it was solid; and by consequent follows
ye same rules in respect of ye swiftness at its fall as
a cylinder or ice or ye same back viz that beginn=
=ing with a very small space it is augmented in pro=
=portion according to ye odd numbers 1 3 5 &c that is
to say that in ye 4th of a second it should descend
1 foot ye 4th following it would descend 3 feet in ye 3 5
feet, &c whence it follows that ye water wch was in
A being arrived to B shall go out swifter than that
wch went out first.



Galileus hath spoken well of ye acce=
=leration of ye swiftness of bodys wch fall in ye first qua=
this is as I conceive it. If there is some very light bo=
=dy wch dasheth against another body 100 times more
heavy, it will give it ye 100th part of its swiftness
and striking it ye second time it will give it yet ano=
=ther 100th part so that if a body striking hath 101
degrees of swiftness ye body struck shall take one degree
at ye first shock and ye quantity of motion shall be 100
and being struck a second time with ye same swiftness
of 101 degrees by ye light body, it will receive a new ac=
=cess of swiftness, wch joyned to ye other shall make 2
degrees: ye third shock shall add yet to it one degree and
so on as it is proved in ye treatise of ye shock of bodys: ye
same thing will happen if any feeble power draws to
it a very heavy body drawing it by silk now let a body
be drawn or pushed by a matter very light it ought
to happen that it at ye first moment of its effort it pas=
=ses a line by an uniform swiftness, that is at ye 2d shock and at ye 2d moment it will goe 2, at ye
3d moment 3 &c:

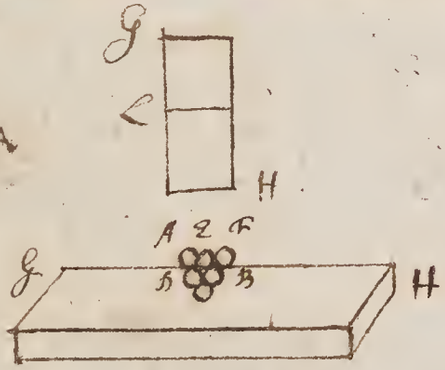
Now if we take many numbers together beginning at a unite as 1, 2, 3, 4, &c to
20 and we count 20 numbers; ye sum of that progression shall be 210; and if we count 40 moments
according to that progression ye sum of these last numbers shall be 820, wch is near 4
quadruples of 210 ye sum of ye 20 first numbers: but at infinity that last sum shall be exact=
=ly 4 quadruple of ye first, since ye proportion that is wanting always diminisheth; wch
Galileus hath also excellently observed in his treatise of ye acceleration of bodys wch fall: but if ye motion
be made cross a fluid body very heavy, ye acceleration shall be presently stopped, and ye falling body
is reduced to an uniform swiftness; as also if it is a very light body wch falls through ye fluid air, as he
hath proved in ye treatise of percussion.

We may judge also of ye gentleness of ye going out of ye first drops of water when ye spirit
is uniformly forced by ye following experiment. Take
a crooked pipe of 2 or 3 feet high as CBG equally large
that out, now water thro C till it runs out at G, stop ye
end G, an continue to fill ye pipe to C, put either upon ye
other fingers upon that end, and open ye end G, ye water
shall not run out if ye pipe is but 3 or 4 lines large take
away ye fingers with ye end C, and clap it on again very
speedily, ye water shall not spout thro G but to 4 or 5
lines high, but if ye pipe CB is very much longer than
ye hole G, for example if it is 9 lines long and ye
end 2 or 3 lines, and that you open and shut with ye
same swiftness ye small hole in G, ye drops of water
wch go out at G, do spout very near to ye height C ye
may know also ye same slowness of ye water at its first
going out of ye pipe as AB (in ye figure of page 125)
and its acceleration, if you fill with water that pipe
and it sustaining it with your fingers, you sustain also
a small stone with another finger of ye same hand:
then suddenly drawing away ye hand from with ye
stone and ye bottom of ye water descend with ye same
swiftness to 12 or 15 feet



There is made also a very curious experiment
to prove this rule, in ye following manner:

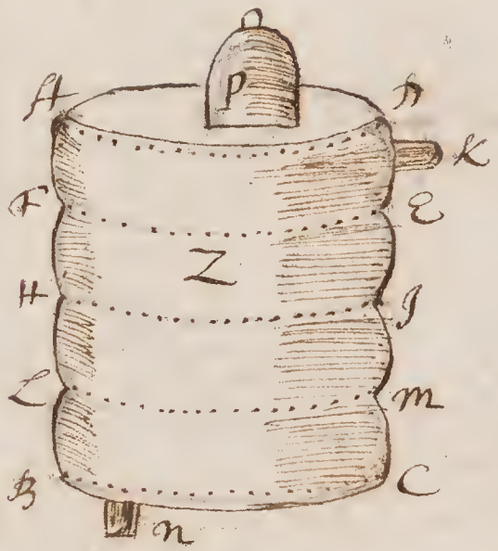
of ye second rule take a Long pipe of 8 or 10 feet heigh as mn in ye following figure
wch sustain with ones fingers and permitt it to run on ye suddain upon ye rule R neer
ye point R, wch rule leaning as a balance ought to be Horizontal and supported by ye other
end upon a common fulcrum as O, and that point R ought to be distant only 5 or 6 Lines
from ye bore of ye pipe thro wch ye water runs; that is to say a line more than ye thick=
=ness of ye finger wch sustains ye water; then if at ye other extream Q there is a weight
smaller by one 4th or one 5th than ye weight ~~X~~ of ye cylinder, than ye weight of all ye wa=
=ter of ye cylinder, ye weight Q shall not be elevated at ye beginning of ye fall of ye water altho
we see that they are only ye first parts of ye water that make ye impression, and that when
they go out very slowly as they go at ye beginning of their fall, they can elevate but a weight
Less than ye weight of ye whole cylinder: but that when they have acquired a certain swiftness
in falling from ye height m, those wch remain elevated by their shock that wch is first could
not elevate by their small shock at ye beginning of their fall. But if we elevate ye same
pipe 2 or 3 feet above R and that we leave ye water at ye bottom of only one inch heigh,
if ye pipe is 7 or 8 lines Large, it will make Less impression in falling upon R to elevate a
weight m 2 than a bullet of wax or wood Less heavy than its halfe falling of like height;
whence we see that ye bullet makes its impression by all its parts and ye water of an inch
heigh only by those most near to ye ~~water~~ first surface wch shakes ye ballance, and wch
are a Little aided by ye Lower distant. wch must also be allso ye water do not act in its
falling by all its parts, and that it is difficult to determine to what height of ye water we ought
to take them; it is however very probable that ye first wch fall act ye most, and that those
wch are a Little higher to 2 or 3 Lines, a Little Less, and so to 5 or 6 Lines as it would happen
to 5 or 6 small grains of sand contiguous one
to ye other A E C F D B falling upon a rule G H
from a certain height not being all in ye same
perpendicular Line, ye A D and B do never=
=theless contribute to ye shock at ye first a little
although they do not do it with all their weight
and all their swiftness, not being in ye same
Line of direction of heights A G C F contribute
also a little and make that ye rule shall be
stroke more strongly than if there had been
only B and E.



Law ye water being composed of an
infinite number of very small contiguous cor=
=puscles very much smaller than ye small grains
of sand, which would and glide easily one against
ye other, a small cylinder of water as G H shall give a Little greater shock than a Less E H.
since there is more of ye small particles placed indirectly one upon ye other in ye height
G H than in ye Lesser L H

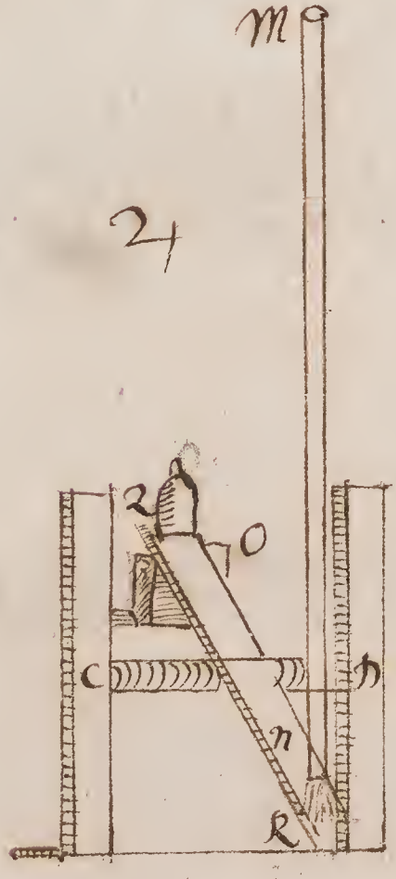
Rule II

The water wch spouts out at ye bottom of a ~~vessel~~ reservatory by some small
round hole, makes an equilibrium by its shock with a weight equal to ye weight of a cylin=
=der of water wch hath for its base that hole, and for ye height that from ye center of ye
hole of ye upper surface of ye water.



of ye orifice n is to ye entire surface of ye

This proposition may be demonstrated and at ye same time ye force of ye air in this feat. A B C b is a hollow cylinder whose two bases A b, B c are of wood, and ye rest of copper, sustained and extended by many circles of wood crosswise F E, H I, L m, so that we can bring down ye base B c wch is supported immoveable in a hole made in ye base B c thro wch ye inclosed air in ye cylinder may go out; that cylinder is charged with a weight b placed upon ye surface A b and it wil sit below ye cylinder as a ballance as that of ye figure marked 2, so that ye rule Q R being situated horizontally ye point R wch is near to its extremity may be very near ye hole n, and directly below its centre: this being supplied I say that if we put a weight Q upon ye other end of ye ballance whose support c b is supplied to turn easily upon ye points C and b, and that ye air, wch ye weight P in descending makes to go out with much violence thro ye hole n, dasheth against ye extremity of ye ballance towards R makes an equilibrium with ye weight R supplied equally distant from ye support c b, that weight shall be to ye weight P in ye same proportion as ye surface of ye base B c: for if by means of a bellows wch hath its hole equall to ye hole n, ye air is pushed against that hole with a force equall to that of ye air wch ye weight P makes to go out, there shall be made an equilibrium between these two forces or ye weight P shall not descend because there will no air go out thro ye hole; and then ye air pushed by ye bellows hitting that hole will sustain its part of ye weight P, as ye other parts of ye base B c sustain ye rest of ye weight, and then ye part wch ye pushed air will sustain shall be to ye entire weight P in ye proportion of ye hole n to ye entire Lowgness of ye weight B C; therefore reciprocally ye air going out at that hole after we have taken away ye bellows, shall make an equilibrium by its shock with a weight wch shall be to ye weight P as ye hole n to ye base B c. but if we stop ye hole n, and open another of ye same Lowgness as at ye point K ye air will go out with ye same swiftness as by ye hole n, if ye base A b is charged with ye same weight P, and will make an equilibrium with ye same weight by its shock.



But if ye cylinder is successively charged with divers weights to make ye surface A b descend more or less swift, ye air wch will go out thro ye hole n, shall make an equilibrium by its shock with weights wch are one to ye other in ye same proportion as ye weights wch successively charge ye base A b: ye reason is that ye proportion of ye great weight P to ye small wch makes an equilibrium, is always ye same as that of ye base B c to ye hole n; whence it follows that ye small weights shall be one to ye other in ye same proportion as ye great weight that shall be put upon ye surface A b. but if we fill ye same cylinder with water, ye spout wch shall be made thro ye hole K by ye effort of ye weight P, shall make

ye same effect as ye aire: that is to say shall make an equilibrium by its shock with a weight wch shall be to ye weight P as ye hole K to ye whole base B C because that then ye weight of ye inclosed water will contribute nothing sensible to ye force of ye spout, since it is allways below; and that if a spout of water of ye same Largeness and swiftness should strike ye
= directly in K that wch goes thrô that hole it would stop an make an equilibrium with it and would sustain one part of ye weight P according to ye proportion of ye hole K to ye surface B C: whence follows a paradox enough surprising viz that ye aire and ye wa-
= ter wch go out successively thrô ye same hole K, whatever weights we put upon ye base A B, elevate ye same weights by their shock, altho ye water be a matter much more dense and heavy than the aire: but it happens after wt recompense that ye aire goes out much swifter than ye water for we have found by many experiments, that when a cylinder is full of aire, it is void in about 24 times a less time than when it is full of water.

For example if ye aire is emptied in 2 seconds ye water shall not be emptied but in 24 seconds whence we may conclude that to ye end a spout of ~~water~~ aire may make ye same effect by its shock as a spout of water of a like Largeness, it is necessary that its swiftness be about 24 times greater than that of ye water.

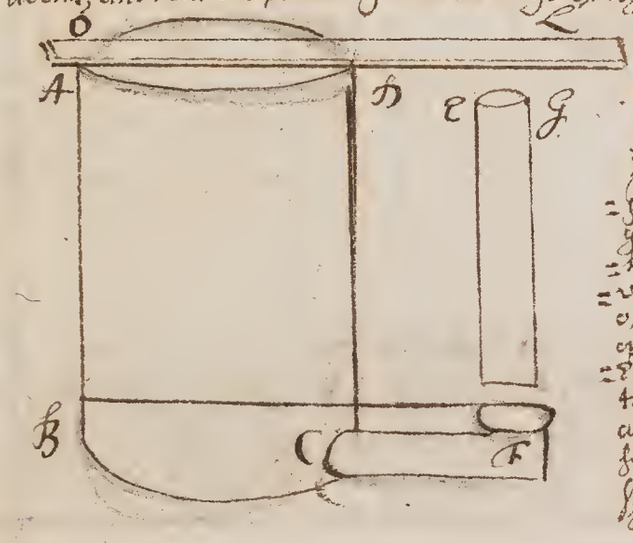
Now ye same effect ought to happen, if A B c h is a cylindric vessel full of water, and open at ye top: for ye water wch ought to spout thrô ye hole n being stopped by another spout
= that meets it directly at ye point n, that spout will sustain one part of ye water of ye whole cylin-
= der; viz ye cylinder wch hath for its base ye hole n, and ye rest of ye base will sustain ye rest of ye water: therefore that spout being taken away, ye spout wch will go out thrô ye hole n, shall make an equilibrium by its shock with a weight wch shall be equal to ye weight of that small cylinder wch hath for its base ye hole n, and ye height equal to A B; if ye cylinder A B c h is wholly full.

Rule III

The spouts of waters equally Large wch go out thrô ye small holes made at ye bot-
= tom of many pipes full of water of different heights make an equilibrium with weights wch are one to ye other in proportion of ye heights of the pipes:

Explication.

Let there be a great pipe A B and a Less c h pierced at ye points E and F with equall holes c big
= Vp: 51 and 71 it hath been above that ye waters spouting thrô ye hole E shall make an equili-
= brium with a weight equall to ye weight of ye cylinder of water E G, and that ye spout wch goes thrô F shall make an equilibrium with a weight equall to ye cylinder of water F H: now these small cylinders having equall bases by ye supposition will have their weights in proportion to their heights: whence it follows that ye weights with wch these spouts make an equilibrium shall be one to ye other as ye heights A B, c b; by consequent it is evident if ye first swiftness of a spout issuing out ought to be such that ye first drop of water wch goes out be disposed to be elevated to ye height of ye upper surface of ye water: For supposing that ye water was in ye Lower cylinder A B c b at b and that there was a cylinder of ice of ye Largeness of ye hole F, wch goes not but from F to G and wch was suspended from that point directly upon ye hole F at ye distance of $\frac{1}{2}$ a line or there abouts, and that we permit ye water to go out a little, it will make ye cylinder F G mount to ye height



by its shock since it can make an equilibrium with a cylinder of ye same Largeness and height, F E: but if ye water should spout but to ye point F, it could not stay at ye elevation since ye force of ye water following would push it higher, it is
= even as a cylinder of ice whereof we may judge that ye first drop would be elevated to A E without ye re-
= sistance of ye aire joined to that that ye waters wch goes thrô F bring changed en height to make an equi-
= librium with ye water A b, ye first drop that is ele-
= vated ought to have ye force to mount to ye top of ye superior waters of ye reservatory, if we make an abstraction of ye resistance of ye aire: as is explain-
= ed in ye first discourse, where it is made evident that in ye elevating to an equilibrium, it spouts also strikes them ye superior waters by reason of swiftness acquired by ye great motion that ye spout takes to be elevated to the height of the superior waters:

Having filled with water ye reservatory A B C b of 16 inches heigh above ye hole of ye spout in F fill it may passe above ye edges about a Line: for although as it hath been said it doeth not run over when it is about a Line and a halfe or 2 Lines above particularly if ye sides of ye reservatory are rubbed with greasse, we put upon ye top a rule of iron Horizontall & transe=-cient, wch was by consequence about a Line lower than ye upper surface of ye water; and we observe that permitting ye water to spout a little obliquely thro' ye hole F and keeping ye pipe A B C b allways full to a Line above ye base of that rule, ye height of ye spout would go to that rule, wch would be known by a little water wch would stick to it, wch had yet force enough to be elevated a little higher of one fourth of a Line: but when ye water was but even with ye reservatory, and could not passe over, ye brinks, there would no water stick to ye rule, because ye air would resist a little ye force of ye spout.

But if ye pipe was 2 feet heigh there was need of somewhat less than 2 Lines that ye spout might not go to ye rule: but when ye reservatory was of a less height as 7 or 8 inches, and ye holes were of 3 or 4 Lines diameter, ye spouts would be allways elevated sensibly as heigh as ye surface of ye water be caught that little air they have to passe thro' cannot sensibly dimin=-ish their force.

Now by ye doctrine of Galileus a drop of water wch is elevated to ye height of 2 or 3 feet when in falling down again it is come to ye point whence it began to be elevated, it ought to take at that point ye same swiftness wch had elevated it; whence it follows that we may take it for a Law or Axiome of nature that ye water wch spouts at ye bottom of a reser=-voir by a small hole, hath ye same swiftness as a grosse drop of water should have had in falling from ye height of ye surface of ye water to ye hole filled for it, abstracting from it ye resistance of ye air.

Consequence

It follows that ye swiftness of ye water wch goeth out at ye bottom of reserva=-torys wch are of an equall height, are one to ye other in a subduple proportion of those heights; for since ye swiftness of each spout ought to elevate them to ye height of their reserva=-tory, and that by what Galileus hath demonstrated, ye bodys wch are moved with different swiftnesses, are elevated to ye heights wch are one to ye other in a double proportion of their swiftnesses; it follows that ye swiftnesses are one to ye other in a subduple proportion of ye heights

Rule IV

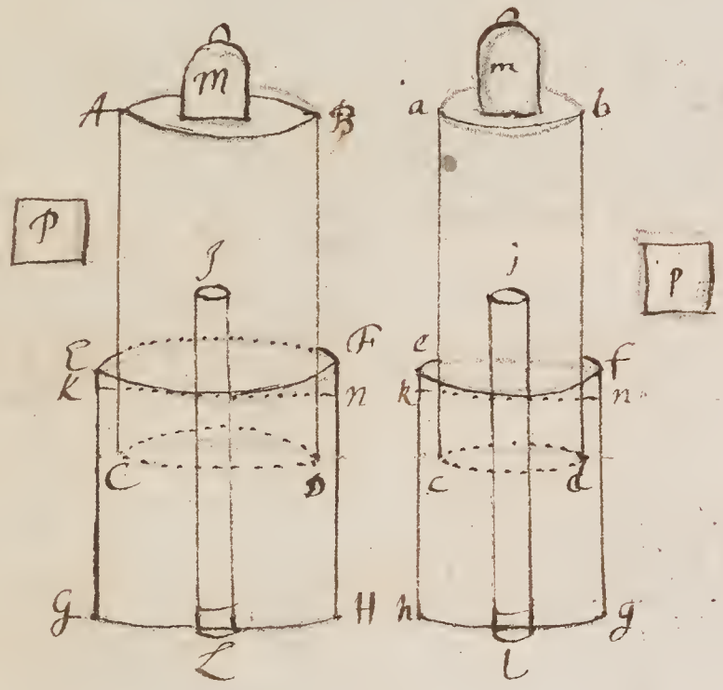
Shock weights Spouts of water equally large wch have unequall swiftness, sustain by their Weights wch are one to ye other in a proportion double of those swiftnesses:

Explication

For as much as ye water may be considered as composed of an infinite number of small imperceptible parcells, it ought to happen that when they go swift as swift, there is twice as many wch shock at ye same time, and for that reason a spout wch goeth swift as swift as ano=-ther, makes twice as great an effect by ye multiplicity of ye small bodys wch shock: and because it goeth twice as swift it makes yet twice as much effect by its motion; and by consequence these two effects together ought to produce a quadruple effect, and ye same in respect of other propor=-tions. we may moreover prove this rule in ye following manner (Fig: p 5 and 9) I: A B is a cylinder 4 times as heigh as ye Cylinder C B, ye hole E is equall to ye hole F, ye two cylinders are full of water: now for as much as ye spout going out at E ought to sustain a weight equall to ye weight of ye small cylinders of water G E, and that ye spout thro' F ought to sustain a weight equall to ye weight of ye small cylinder H F, and that ye small cylinder G E is 4 times ye small cylinder H F; it follows that ye weights elevated should be as 4 to one; but by ye consequent of ye preceding rule, ye swiftness of ye spout thro' F is to that of ye point thro' E in a subduple proportion of ye height F H to ye height E G, and by consequence it shall be as 1 to 2: therefore a double swift=-ness of a spout of ye same largeness shall sustain a weight 4 quadruple and so in respect of other proportions; whence it follows that a spout of air wch goeth 24 times as swift as ano=-ther shall sustain a weight 576 times greater, since 576 is ye square of 24; and because a spout of water wch goeth 24 times slower, sustains ye same weight we may judge that ye air is 576 times more subtile than ye water since that going with ye same swiftness ye spout of water sustain a weight 576 times greater.

we may know by experience ye force of ye shock of ye air with ye following engine as well as with that of ye second rule: A B c b is a cylindrick vessel of iron well sod=-dered even in c b, and inverted in another cylinder E F G H at ye bottom of wch there is a small pipe well soddered I, wch enters into ye inverted cylinder and passeth a little above ye water in K, wch is in ye cylinder F H ye base A B is with many different weights to make that cy=-linder descend, and at ye same time make ye air go out with violence thro' ye pipe I L at ye end of wch is fitted a ballance as that at ye figure above marked 2, charged at one end with different

weights to try ye force of ye shock of that aire. ye experiments are found conform=
=ble to ye demonstration
above, viz that if ye aire
is blown with a bellows into
ye pipe L l that it hinders
ye weight m and ye cylin=
=drs A b from descending
then that pushed aire makes
ye same effect as it one's hin=
=drs was put at ye point L
to hinder ye aire from go=
=ing out, and as in the last=
=case ye finger would bear
its part of ye weight m,
joyned to that of ye cylinders
A B, and ye rest should be sus=
=tained by ye air of ye base G H to
ye height of c B to ye hole
L; so that if ye whole weight
was 100 and ye base G H was
100 times as great as ye hole
L ye aire blown into ye pipe
would sustain ye 100 part of
ye whole weight: therefore
reciprocally we take away
ye blast of aire wch should
go out with ye same swiftness
as ye wind of ye bellows will
would hinder its going out,
will make an equilibrium
with a weight equall to that
of 100 point.



It follows for these reasons, that if two cylinders full of aire of ye same height having their bases m equall are charged by equall weights being disposed as ye cylinders A B c b, a b c d put each in another cylinder full of water, as it hath been explained in ye figure preceding, and let ye two weights M and m be equally placed upon m equall cylin=ders, and ye weights elevated be P and p viz P for m and p for m, for as much as ye base G H is to ye hole L as ye weight m to ye weight P elevated by ye aire wch goeth out thro L to=wards ye weight m or m; in equall reason. ye proportion being inverted, ye base G H shall be to ye base gh as ye weight P to ye weight p. but if ye weights wch change ye cylinders are proportionall to their bases, they elevate equall weights by ye shock of ye aire wch they make to go out thro ye equall holes, as if ye base G H is 24 and ye base g h 12 and that ye weight M may be 12 pounds and ye weight m & ye hole L being 4 ye same as b, ye weights P and p are each of 2 pound, of wch ye proof is easy:

Consequence
Of ye former demonstration

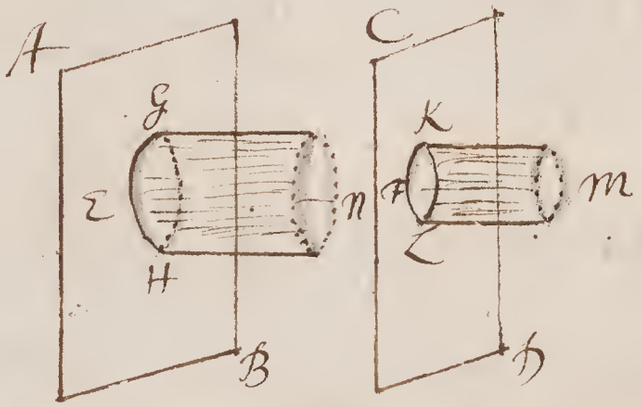
It follows that ye time of ye running out of ye aire of ye small cylinder shall be to ye time of ye running out of ye aire of ye great cylinder, when they are charged with equall weights, in a proportion compounded of that of ye base G H to that of ye base g h and ye subduple of ye same base G H to ye same base g h; for if ye swiftness were equall, ye times would be one to another as bases: but ye weight elevated being in a reason reciprocall of ye bases and ye swiftness being by ye third rule in a subduple reason of ye weights elevated, ye swiftnesses will be re=ciprocally in a subduple reason of ye bases that is to say that ye swiftness by I shall be to ye swi=ftness by L in a subduple proportion of ye base G H to ye base g h; and by consequence ye times of ye running out of ye aire of ye great cylinder shall be to ye time of ye running out of ye aire of ye little cylinder in ye proportion compounded of that of ye base G H to ye base g h, and ye subduple of ye same base one to ye other, wch is found conformd to experience: for a cylinder of 8 inches 7 Lines diameter at ye base, and another of 5 inches 6 Lines being charged each with 44 ounces ye great one is void in 47 half seconds and ye little one in 12: now ye bases G H and g h are one to ye other as ye squares of their diameters G H and g h; and 74

pricks wch is neare ye square of GH of 8 pricks 1 lines 33 to 30, wch is neare ye square of gh of 5 pricks 6 Lines, as 47 to 19 neare; and as 74 to 47 ye mean proportionall betwen 74 and 30, for 47 to 12; whence we see that 47 is to 12 in a proportion composed of that of ye base GH to that of ye base gh, and of ye subduple proportion of ye same base GH to ye same base gh.

Rule V

Spouts of water of ye same swiftness and of different holes sustain weights by their shock wch are one to ye other in a double proportion of their holes:

Let ye two surfaces AB, CD be pierced at ye holes E and F and that ye two spouts of water part these holes: it is evident that ye surface of ye hole E is to ye surface of ye hole F in a duple proportion of ye diameter KL, and ye swiftness being supposed equall, if ye diameter GH is double to ye diameter KL there will be 4 times as many small corpuscles of water to shoc in ye base GH as in ye base KL: they therefore make a quadruple effect, and if ye surfaces of ye spouts are reciprocall to ye weights of ye reservations, they make an equilibrium with equall weights.



To know ye force of running waters when they strike ye wheels of mills or some other engines, we must know their swiftness and compare it to that of water wch spout at ye bottom of a reservatory. It is therefore necessary to know ye specific weight of ye water in regard of other bodys, here are ye observations wch I have made.

There was made a vessel of copper square of half a foot height, wch by consequence, would contain ye 8th part of a cubic foot; it was put into ye scale of a ballance and on ye other side a weight equall to it, it was filled afterwards with water with very great care by a small hole made towards ye angle of ye uppermost side: we found by experiments that ye water would weigh 8 pound 3 and by consequence that ye cubic foot of water ought to weigh 70 pounds, a muid of Paris contains 8 cubic feet, in each cubic foot 36 pints when they are measured just and that ye water doth not pass ye edges but when it passeth ye edges ye most it can without mounting over, it contains but 35 pints; each of ye last pints weigh 2 pound and ye other 2 pound less by 1 gross ye muid of Paris contains 285 pints of these last, and 280 of ye other, whence is known that a cylinder of water whose base is a foot diameter and a foot height weighs but 55 pounds, since ye proportion of ye circle to ye square of wch is circumscribed is neare ye neare as 11 to 14: now as 14 to 11 so 70 pounds are to 55 $\frac{1}{7}$, whence may be known that a cylinder of a foot height and of a inch base weighs 7 ounces one gross neare; for ye 14th part of 55 pounds is 3 $\frac{6}{7}$ ounces and a gross is $\frac{1}{8}$; upon wch ye following experiments are made.

Having tyed a small stick to another great one wch was immoveable in ye middle of ye course of ye river where it was very swift, we measured a long from ye small stick a distance of 15 foot in length, we cast afterwards a small peice of wood or some peice of an herbe at two or 3 feet from ye stick, over against ye place where ye first mark of 15 feet was, and we counted by a pendulum that beat half seconds in what time it passed to ye other mark, if it was in 10 demiseconds we concluded that in that place ye water of ye river went 3 feet in a second. afterwards we made use of ye turnpike where there was two rules wch crossed at axis, so that ye plains where they were cut one ye other at right angles. there was elevated towards ye end of one of these rules a small square board of 6 pricks Large very fine, wch was dipped perpendicularly into ye running water till it passed 4 or 5 pricks above it, and at ye same time there was put at ye extremity of ye other rule wch was in an horizontal situation, a weight equally distant from ye axis as ye middle of ye board: ont it was augmented or diminished till it made an equilibrium with ye shoc of ye water against ye small board or shovell. many of these experiments were

made at ye place were ye water was most swift, and in other places where it went less swift, and ~~other~~ there was found always very neer ye same proportion correspondent, to that force of ye water wch goeth out at ye bore of a pipe of 12 ~~feet~~ high: Here is ye manner of calculation.

Having found that ye water in ye swiftest place made $3\frac{1}{2}$ feet in a second and that it sustained then by ye shoc of ye shovel $32\frac{1}{2}$ pond ye front at ye bore of a reservatory wch is 42 foot height as ye swiftness at its going out to make 24 feet in a second according to ye doctrine of Galileus and wch hath been explained above, that swiftness of the water about $7\frac{1}{2}$ is $56\frac{1}{4}$ and by consequent it ye front is of ye same largeness as ye shovel it ought to sustain a weight about 56 times as great: now 12 cubic feet of water weighs 8640 pond, whereof ye 4th part is 2160 pond wch we take because that ye shovel is but half a foot, and that a column of water of half a foot square at ye bore and 12 feet heigh, weighs 210 pounds; and if we divide 210 by 56 ye quotient shall be about $3\frac{3}{4}$ pounds wch is ye weight wch hath been found in ye experiment.

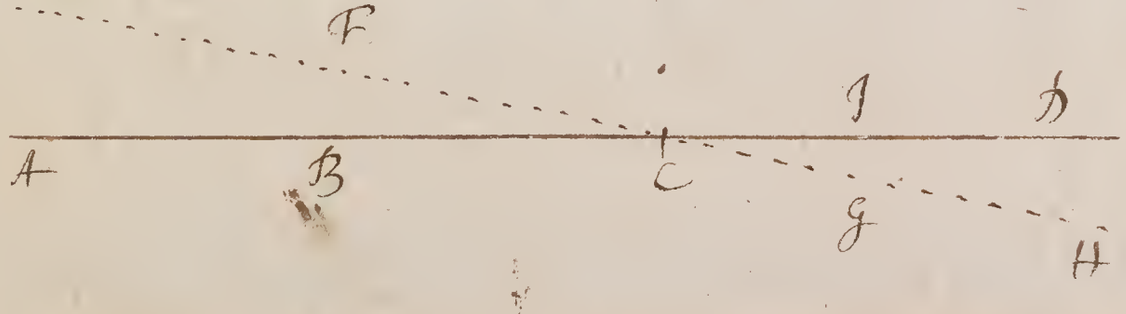
I have found likewise ye force of ye running water in many other places of ye rivers and also in ~~the~~ Aqueduct of Arcueil. I made an experiment at ye side of ye river where ye running water made $1\frac{1}{2}$ foot in a second and it made an equilibrium with 9 ounces of weight to compare it to ye swiftness of $3\frac{1}{4}$ feet we must take ye sq: of ye $1\frac{1}{2}$ wch is $\frac{25}{10}$ contained about $6\frac{3}{4}$ times in ye square of $3\frac{1}{4}$ wch is $10\frac{2}{16}$ ~~too~~ ye product of $6\frac{3}{4}$ by $\frac{25}{10}$ ~~is~~ is 9 and 64 wch is a little more in value than 60 ounces wch make $3\frac{3}{4}$ pounds.

The wheels of ye mills wch are ~~upon~~ upon ye Seine at Paris between ye Pont-neuf and ye Pont-au-change, have not at their extremity but half of running water wch shocs them wch amounts to ye same thing as when a weight in motion encounters another of ye same weight, wch is immovable and that it is forced thereby, for being forced together they have lost immediately either ye shoc but ye half of ye swiftness of that wch hath shoced, and so we may suppose that ye resistance of ye rubbing of ye axis of ye wheel, of that of ye mill-stone and of ye corn wch is grounded, joyned to ye weight ~~of the~~ of ye wheel and of its shovels, amounts near to as much as ye resistance of a weight equall to that of ye water wch shocks and by consequence they ought to retard near half of ye swiftness of ye water wch shocs them; ye same proportion is observed in ye wheels of ye pump:

It is necessary here to consider that ye water of a river doth not go equally swift at its surface, and in other parts; for ye water near ye bottom is much hindred by the encounter of stones herbs and other irregularitys.

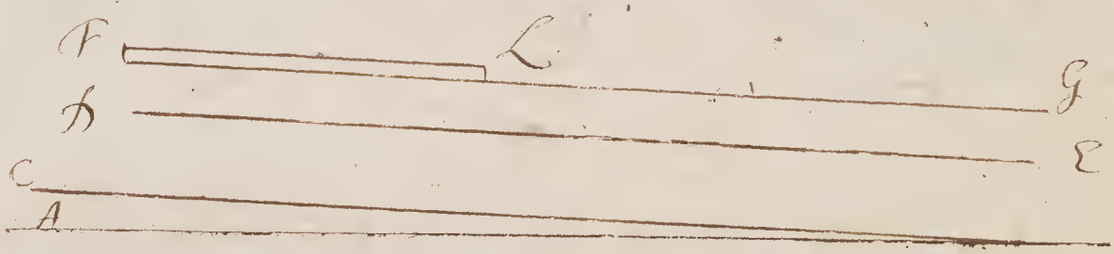
Here are ye experiments I have made of ye ~~difference~~ swiftnesses.

I put into a small river running uniformly balls of wax tyed to a thread of a foot long, one was charged with small stones in ye middle to render its specific gravity somewhat greater than that of water, so that when ye 2 balls were in ye water ye heavier tended ye thread an inch or 2 lighter towards than it would have done alone and by that means its upper part was almost even with ye water that ye wind may not blow upon it. I allways observed that ye lower ball would remain behind principally at ye places where there was some herbs at ye bottom of ye water near to wch ye lower ball should pass; for that river was but about 3 foot deep: but when these balls were put in a place where ye water encountring some obstacle was elevated a little, and afterwards took a more rapid ~~motion~~ course, as it is observed under bridges, ye lower ball would not go so upon whence we see that ye water in ye middle goeth then swifter than at ye surface; and this proceeds from thence that ye water being elevated a little higher by ye obstacle, acquires a greater swiftness in mining thro a steepy place and that violent motion makes it plunge it self and pass below that of ye surface; as A B c b



is ye course of ye superior water, and that by an obstacle towards B it is elevated to ye pricked line E F, it will run swifter thro ye steep place E F C and by ye swiftness it hath acquired

in C it will continue its direction below c b as in g H and by consequence will go swifter
in G and H than in I and K, and from hence proceeds that in moderate rivers there is always
great holes a little below ye bridges; it is seen by experience in ye bridges of ye county of Norf
upon ye Seine: For ye water wch is elevated by ye combring ye piles of ye bridge takes a greater velo=
=city and passeth with violence below from ye top to ye bottom where it carrys ye sand and
gravel a little lower where it is level up: but when ye water is in ye bridge in its
ordinary course and motion, ye superficies ought to go swifter than that wch is a foot below
for let A B be an horizontall line and c b ye steep place of ye bottom of ye river, b E ye water
wch is half a foot from ye upper most F G both parallell to c B now because ye water is
viscous and by contiguity hath and a little force together ye water D E will carry that
wch is immediately above with near ye same swiftness; and likewise that wch is in c F, wch
is moved as well as it because of its steep place, goeth somewhat swifter than ye water b E, wch



one may by below comprehend if we suppose F L a board swimming upon ye water, and that ye
upper side may be a little steep parallel to c B, having a very round ball at ye upper side, for
that piece of wood carried by ye water would carry ye ball, but would not feel along
by bound to G, and by consequence its swiftness would be greater than that of ye board.

I have more over oftentimes observed ye herbs wch ye water would carry away
and did see manifestly that those wch were between two waters near ye bottom moved
=ver more than those wch were at ye surface, were soon passed and left behind by ye superiour;
and if I should cast into ye same river an hand full of small sawdust or wood wch would go to
ye bottom, I should always see ye superiour precede ye others in proportion as they were more or
less distant from ye bottom; by wch experiments it appears that in rivers wch run swiftly
ye upper water goeth swifter than that of ye middle and that of ye middle swifter than that
wch is near ye bottom, and that in those wch are constrained to pass thro a narrow bed, being
retained on both sides, that of ye middle goeth swifter than that of ye surface if it is but 3 or
4 foot deep.

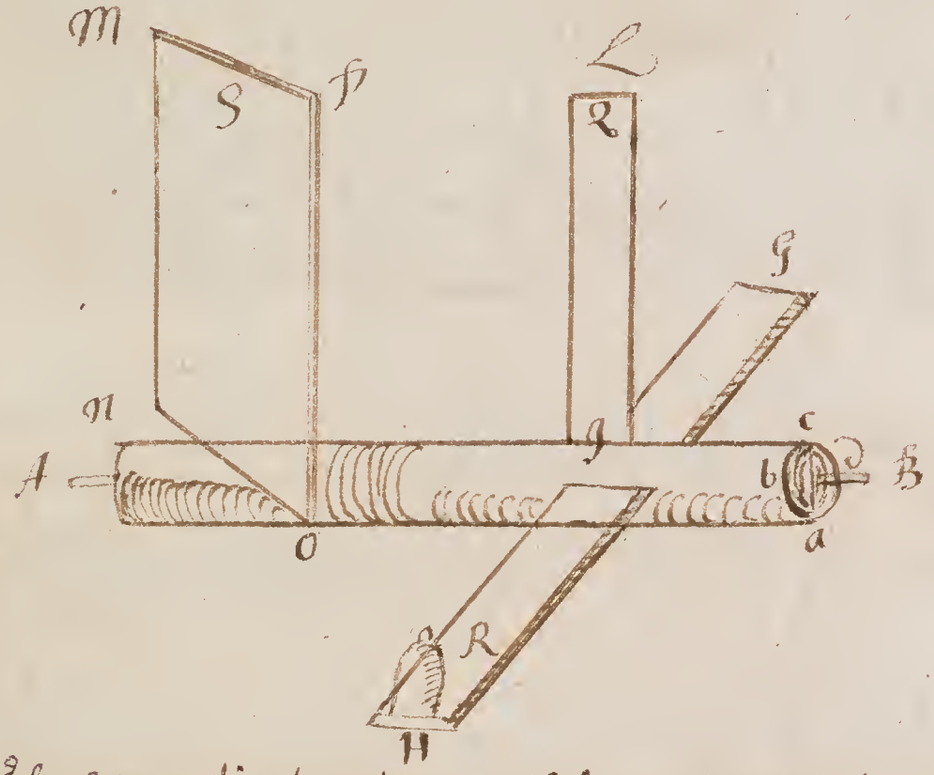
This is ye way to calculate ye force of ye mill wheels at ye Seine.

I suppose there is two wheels to one axis that they have 8 feet semidiameter,
and that ye boards wch is called aubes) wch serve for shovells are two feet high in ye water and
5 feet long: I suppose also that ye swiftness of ye water wch strikes ye shovells is 4 feet in one
second which is ordinary; for it is elevated a little by ye incounter of ye post wch carrys ye wheel
and by consequence goeth over against ye middle of ye post swifter than it if had not been
stopped: now as it hath been said about a superficies of 12 feet high fronting below 12
feet a square spout of 1 foot large, can sustain 210 pound; its swiftness wch is 24 feet
in a second is 6 times as great as that wch strikes ye mill wheels: therefore that water wch
strikes a shovell of half a foot ought to sustain but ye 36th part of 210 pounds, by ye brisk
will; therefore it will sustain 5 5/6 pounds. ye square foot will sustain ye quadruple, viz
23 1/3 pounds and because ye shovells of a wheel have 10 superficiall feet they support 233 1/3
pounds, ye other wheel will have ye same force; therefore both will sustain 466 2/3 pound put
in an horizontal rule at ye same distance of ye axis, as ye middle of ye shovells viz 4 feet.

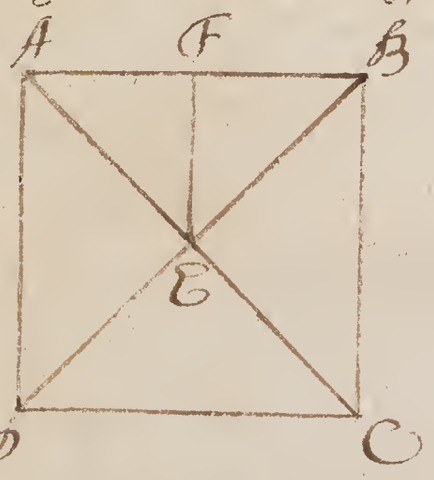
The force of ye shoc of wind against ye sayls of a windmill is found in this
sort.

Take a cylindric Turnpike like to that spoken of in ye foregoing experi=
=ments; A B in that figure represents its axe, g H is an horizontall rule wch crosseth ye
axe of ye cylinder at right angles, I is another rule placed perpendicularly upon g H
m n opposite, yet a perpendicular rule placed obliquely at an angle of 45 degrees in
respect of ye rule g R: now if we suppose a front of water wch strikes directly ye rule
I towards ye point 2, and wch turneth ye cylinder according to ye order of ye letters
a b c d, it will act with all its force to sustain ye weight R: but if another equal force
of water strikes directly ye rule m o at ye point 3 wch is supposed as far distant from ye

axis as ye point R, it cannot sustain ye wright R, because its direction will not be parallel to ye direction of ye extremity of ye sayle FL, and it can sustain but a wright wch shall be to ye wright R as ye side of a lynave is to its diagonal, and if ye same wind is parallel to ye axis AB and strikes at ye same point S, it will be yet needfull to diminish



ye wright R in ye same proportion to make an equilibrium, because that that wind will strike ye sayle obliquely at angles of 45 degrees, and then ye wright R shall have but half of its wright: for if ABCb is a lynave, ye first proportion shall be of AC to AB, and ye second as of AB to AE ye half of AC as it is explained more at large in ye treatise of prevention at ye end of ye 13 proposition of ye second part. now ye wind wch strikes ye sayls of a windmill strikes ye obliquely and if it should incounter each sayle under an angle of 45 degrees, there would diminish to it of its force but according to ye proportion of ye diagonall of a lynave to its side by that only cause; but if that sayle wch is obliquely at ye axis was according to ye same angle; that second cause would diminish also ye force of ye wind according to ye same proportion, as hath been said of a front of walls, and ye total diminution by these 2 causes should be a half of ye force of ye wind, when it shoes ye sayle directly, as if it supposed to be moved at ye beginning according to its direction, so that if its whole force was 80 it would be reduced to 40 by these two causes. but because that ye sayle whose obliquity is 45 degrees receiv something less of ye wind then when it is directly opposed, it would receive yet a third diminution according to ye same proportion of AC to AB and ye whole diminution shall be as AC to EF or neare as 80 to 28½. but if ye obliquety of ye sayle is NO and ye angle of AB and NO be 60 degrees, then ye first cause alone will diminish half ye force of ye wind and will reduce it from 80 to 40 and ye two others together will reduce it from 40 to 31 neare; whence we may judge that it is better that ye sayls of mills have that obliqnity than that of 45:



To know ye force of a wind wch should shoc directly ye sayl of a vessel, we must know ye swiftness of ye wind: it is formerly permitting it to carry away a light bowl from a

stable place, and counting ye time it takes to run thrô a certain place as of 3 or 40 feet. Now supposing ye wind makes 24 feet in one second, as it makes when it is very violent ordina= =rily, however it is much less swift than it is in great tempest and hurricanes it will go as swift as a spout of water wch gosh out of a hole at ye bottom of a reservatory of 12 feet; and ye cause of wind ought to go 24 times as swift as water to produce ye same effect, it shall do no more than water of a like bulk wch gosh but one foot in a second, or a spout wch makes 24, it ye lengths of ye wind is 24 times as great in diameter, or 576 times more in surface. now a spout of water or half a foot semare coming from a reservatory of 12 feet high, may sustain as hath been said above a weight equall to ye weight of a semare column of water wch hath for its height 12 feet, and for as much as a semicircle weighs $\frac{8}{3}$ pounds, if we double that height it shall be $17\frac{1}{2}$ pound for a semare column of a foot height and of half a foot Lengt, and it it is 11 feet height, it shall be 210 pound wch shall be sustained by a spout of half a foot semare. to ye end there= =fore that ye wind wch gosh as swift may sustain ye same weight of 210 pounds it is necessary that ye sayl it shou be 24 times as large and as long as a foot that is to say it is necessary that it be 12 foot both Lengt and long or 6 foot Lengt and 24 foot high, and then if wind wch shall make 24 foot in a second, will sustain 210 pound placed upon a horizontal rule joyned to ye same axis as ye semare sayl of 12 feet in ye same distance from ye axis as ye middle of ye length of that sayl wch ought to be in a perpendicular situation, it ~~will not~~ but if ye wind gosh but 12 feet in a second, it will sustain but $52\frac{1}{2}$ pounds wch is ye 4th of 210 pounds.

If we would make experiment in little, it is necessary to make use of ye Quarpike of and take a sayl of a foot Lengt and heigh, wch having its surface of a foot will sup= =port but ye 144th part of $52\frac{1}{2}$ viz $\frac{5}{12}$ ounces, if that weight is at ye same distance from ye axis as ye middle of that small sayl, but we must choose a wind wch can make 12 foot in a second.

By this means ye different forces of water and wind by their shoc may be easily calculated.

To compare ye force of ye windmills to that of ye mills of ye river spine where of I have spoken, I suppose that each of ye 4 sayls is 30 foot heigh and 6 foot Lengt, there are 180 feet; if ye wind makes but 12 feet in a second it sustains $5\frac{2}{3}$ of a pound in striking a sayl of a foots surface, but if it strikes one of 180 feet in surface it will sustain 36 pounds near: but there must be taken away $\frac{1}{5}$ because of ye triple obliquity is of 30 degrees, there will re= =main therefore 29 pound; and ye four sayls will sustain 100 pound; but ye distance of ye axis to ye middle of ye sayl is 20 feet and that of ye middle of shoots to their axis is but 4 feet. therefore ye shoc of ye wind mills ought to be 5 for, and if ye toothd wheel of each mills 2 times 466 pounds when ye wind gosh 12 feet in a second, and ye remainder of ye water is of 2 feet diameter, ye force of ye wind mill shall be 10 times 100 and that of ye water 4 feet; we may make ye like calculations for greater or lesser swiftnesses of ye water or wind, and for greater or lesser sayls:

Some have attempted to make horizontal mills wch may turn with all winds; I have seen of three sorts:

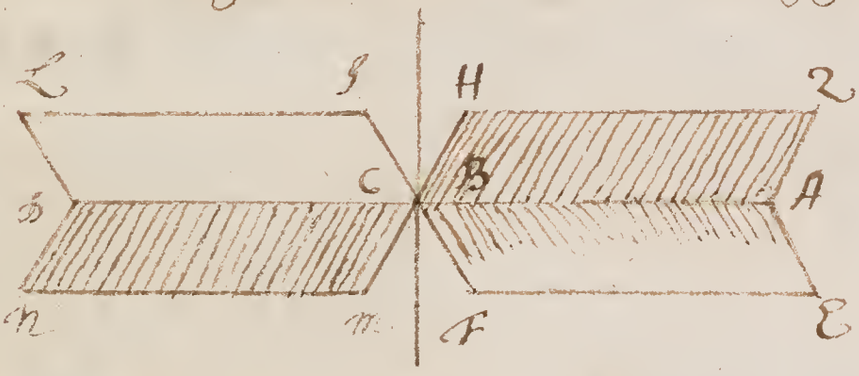
The first had their sayls concave and convex according to an angle of 45 degrees as is seen in ye figure A B is ye height of ye concave, and c b ye height of ye convex,

ye wind blowing betwixt these two will not act after ye same manner, for it will slide on both sides from ye cusp c b along ye plains c L and c N, and will not act but as 5 to $5\frac{2}{3}$ whereas meeting ye concave and not being able to slide away it will act by all its force, as if it had a cloth stretchd upon L 2 H F, and so it will act by all ye force of ye shoc and as 8 and there being 6 like sayls there would be always 3 wch would receive some what less by one third of ye impulse than ye 3 others, wch would necessarily turn ye wheels, but with a little force, for else they must be made excessively great, and so they could not be sustained and would be in danger to be carried away by an impetuous wind.

To prevent them it is necessary that ye angle E H Q be 30 degrees, and then ye proportion of ye force of ye wind shall be in ye concave in regard of ye convex, as 4 to 1 as hath been explained in ye rules of ye fall of bodys at ye end of ye treatise of percussion of ye 3d edition: we may moreover make ye faces c n, c L movable and B E, B Q, that they may fall a little close to ye sail c b, and that they may open to ye others wch would augment ye proportion; it is necessary also to put these 6 sayles two to two one upon ye other diametrw, ye force of ye windmill being 10 times 100 and that of ye water mills 2 times 465 pounds when ye wind goeth 12 feet in a second, and ye current of water 4 feet, we may make ye like calculations how greater or lesser swiftness of ye water or wind, and how greater or lesser sayles

Some have attempted to make horizontall mills wch may turn with all all winds; I have seen of three sorts:

The first had their sayles concave and convex according to an angle of 45 degrees as is seen in ye figure A B is ye height of ye concave, and c b ye height of ye convex, ye wind blowing betwixt these two will not act after ye same manner.



for it will slide on both sides from ye cusps c b, along ye plains c L and c n, and will not act but as 8 to 5 2/3 whereas incountring ye concave and not being able to slide away it will act by all ye force, as it it had a cloth stretched upon E R the F, and so it will act by all ye force of its shock and as 9, and there being 6 like sayles there would be always 3 wch would receive somewhat by one third of ye impulse than ye 3 others, wch would necessarily turn ye wheels, but with little force, or else they must be made excessively great, and so they could not be sustained and would be in danger to be carried away by ye impetuous wind to prevent this it is necessary that ye angle E H Q be 30 degrees, and then ye proportion of ye force of ye wind should be in ye concave in regard of ye convex as 4 to 1 as be in ye concave in regard of ye convex as hath been explained in ye rules of ye fall of bodys at ye end of ye treatise of percussion of ye 3d edition: we may moreover make ye faces c n, c L movable and B E, B Q, that they may fall a little close to ye sail c b, and that they may open to ye other, wch would yet augment ye proportion; it is necessary also to put these 6 sayles two to two one upon ye other that they may receive ye wind ye better and then these mills may produce neer ye same effect, as these we have spoken of:

The second sort had ye breadth of its sayles in a verticall situation, but ye rest wch elevated them was movable planes wch on one side would act entirely against ye extremity of ye wood wch would compass them about when ye wind should blow against them and so they would have receive all ye effect: but on ye other side they would give place to ye wind turning upon ye pivots, and having nothing to stop them, and by that means one part of ye wind would pass between ye opening thus made wch would give much less force than ye other side, and ye wheel would necessarily turn. but it would turn feebly and when ordinary windmills would turn by a moderate wind, this would not turn at all or very gently, because there would not remain ye force of ye wind to move it on ye side wch ye wind would strike entirely, than on ye other, wch would proceed from hence that ye wood and ye cusps parts would there receive as much on one side as on ye other, and ye movable frame by ye side wch they would open would not hinder their falling a little by their weights; and being incountred by ye wind wch would sustain them being neer elevated to an horizontall height: but they would open only about a little more or less: whence they would be useless for ye most part of ye time and would not grind but with violent winds:

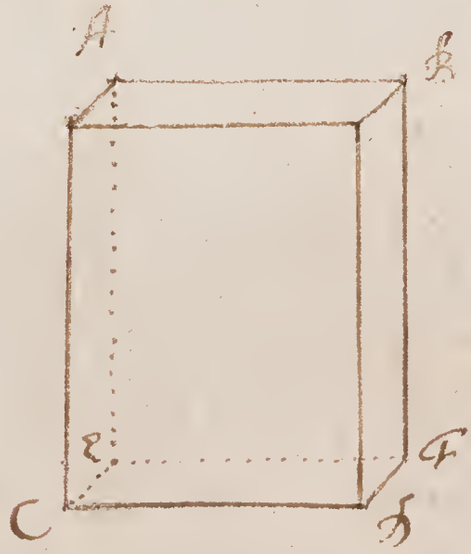
The third manner was by covering ye half of ye number of sayles by a semicylindrick circumference of tin or some other light matter wch was pierced straight to ye wind by a great window cock a great way distant from ye centre of ye engine,

and by that means it had only 3 on one side wch could receive ye impression of ye wind without being hindred by ye 3 of ye other side: but that Engine could not be made in great because of ye enormous greatness wch must be given to ye Semicylindrick cisterns thence and that it would be in danger to be blown away by a more than violent wind:

I have seen also a model of Horizontall wind mills wch are of that sort wch is said to be in use in china, they are made like a Lanterne, there is many sayles wch turn upon Pivots towards ye centre, and ye opposite point towards ye top, and by incountring pegs wch stop them in certain stations to receive ye wind as directly as may be, and when those sayles have made a half turn by ye revolution of ye Engine they turn and comply to ye wind, as weather cocks and they there receive but small impression not to hinder those wch are on ye other side where ye wind incountring them directly or near it; and to that end those of ye other side receive ye wind but very obliquely, and by that means ye wind acts allways more wch move on one side than ye other, wch makes a sufficient effect to ye whole Engine which (often) is placed in ye midst of ye windmill wch is below, wherefore it is not necessary to apply to its wheels and Lanthornes as to other mills by ye rubbing of wch ye force is diminished:

We may by ye same method above calculate ye swiftness of ye wind wch is necessary to overthrow trees or pillars wch should be placed at ye end without shattering any thing; here 13 examples

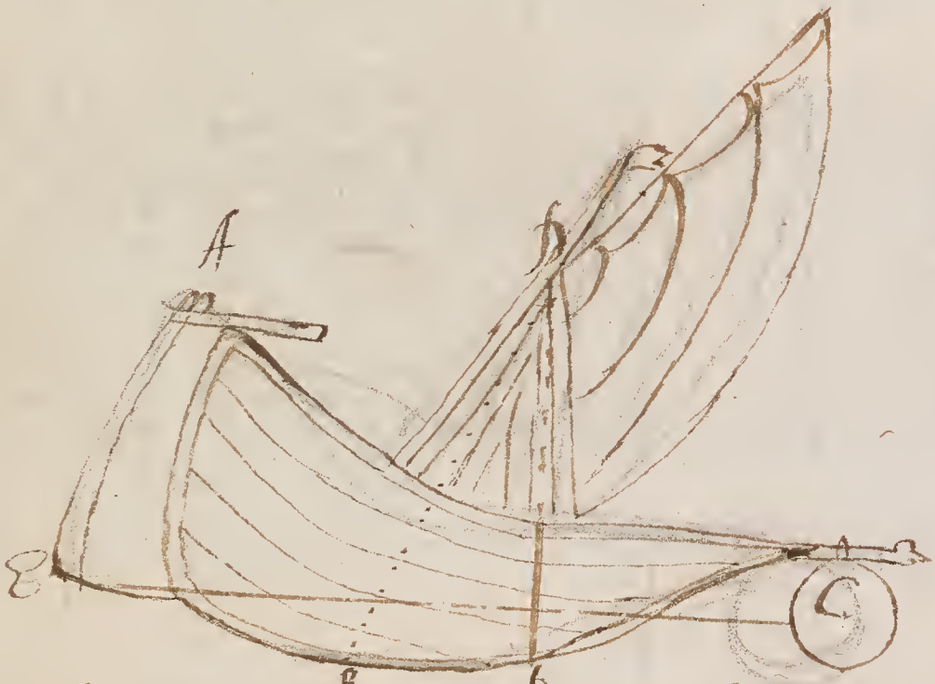
Let there be a square of wood A B C D as that of a frame of paper of a foot large which weight may be one pound and $\frac{1}{2}$ or 20 ounces with its paper neck, exposed directly to ye wind and placed perpendicular upon an Horizontall plane and having ye thin small square sticks of an inch broad: then a wind of 12 feet in a second striking it will sustain near 6 ounces as hath been shewn above and because it is but 12 Lines thick, ye halt thickness where its centre of gravity is should be but 6 lines: now ye weight of ye paper is not considered and because ye distance of its centre of gravity to ye shutter is 6 inches, that wind should act like a Lever of 5 inches to 6 Lines or as 12 to 1, and ye centre of ye motion, ye proportion of ye force of ye wind against ye weight of ye square of 20 ounces should be as 72 ounces to 1 ounce, but ye square of 6 inches by 12 to 20 ounces there must be therefore a Lever, wind to make an Equilibrium and if we take that of 6 feet in a second, it will have but ye fourth of 72 ounces viz 18 ounces and if 36 ye sq: of 6 give 18, 40 will give 20 ounces ye square foot of 40 is something more than 6$\frac{1}{3}$ there will need therefore a wind wch makes 6$\frac{1}{3}$ there will need therefore a wind wch makes 6$\frac{1}{3}$ feet in a second to sustain this square frame: I have made ye experiment at ye top of ye observatory and in ye Samaritane:



After ye same manner will be calculated ye force wch is necessary to break ye branch of a tree of half a foot thickness having ye arm 15 feet and 38 feet of ramous branches and leaves shall be 900 superficiall feet wch ye wind will shoc ye absolute resistance of ye branch to be broken shall be 207360 by drawing a right into ye base for ye absolute resistance of a stick of three Lines hath been found to be 350 pounds A B is ye arm of ye branch B E F B ye compass of ye branches and leaves and C ye centre, ye distance A C is 30 feet ye proportion of 30 feet to ye 3d of ye thickness towards A wch is but 2 inches is of 180 to 1 dividing 207360 by 180 ye quotient shall be 1152 there is need therefore of ye value of 1152 pounds to break ye branch in A there is 900 superficiall feet in ye leaves and branches of ye tree, and because 2 superficiall feet stroke by a wind of 12 feet in a second sustain $\frac{3}{4}$ of a

pound Alby would sustain 450 times 3 that is to say 337 pound neav, wch
4 is a number much less than 1152: set it be therefore as 337 to 1152 so 144 ye
square of 12 is to 49237 whose ye square root is 22¼ neav, there is need there=
fore of a wind wch goeth 22¼ feet in a second to break such a branch of a tree

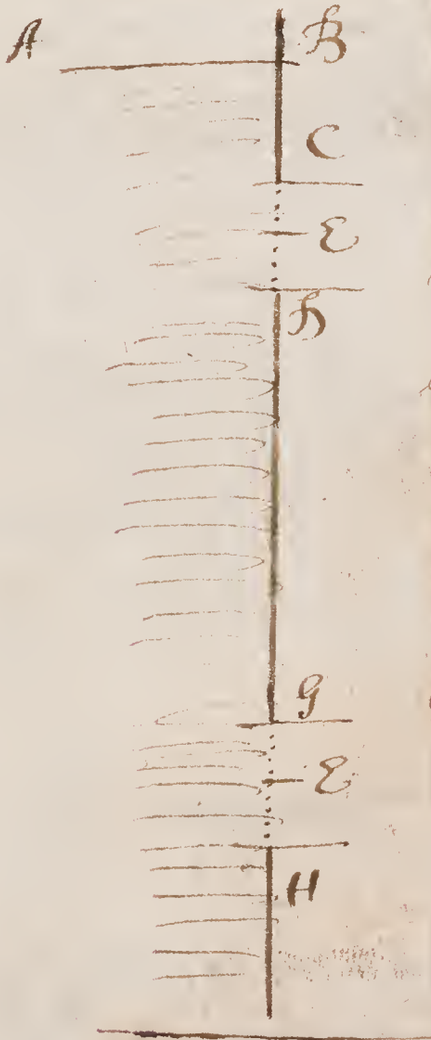
The shoc of wind against ye says of vessels to make them lean or
overturn them followes ye same rules and that of ye equilibrium: for if we put upon
ye vessel A B C whose centre of gravity is in ye line B D, a weight, at ye point C will make



it lean, and ye common centre of gravity shall be in ye line b D, wch in ye water
shall make an equilibrium to it self: and ye weight C to ye weight of ye vessel E ff wch
shall be on ye other side above ye water: now ye sayls being stroke makes ye same
effect as a great weight, and we may compute ye efforts as above, according as ye wind
shall be greater and ye sayls elevated above ye vessel; and observing ye strength above
explained, we may know what swiftness of wind can overturn ye vessel and of that
wch is in it, ye greatness of its sayls, ye obliquity of ye direction of ye shoc comparing
its force to that of a weight as C: but we might consider that ye vessel doth not
turn with ye wind as if it had (effectu)
upon 2 movable pivots and that it is not overturned so easily as it should do: but also
in working it may take a continuation of motion wch being joyned to a great
and sudden puff of wind it may go much beyond ye equilibrium and overturn it:
at ye point B wch might turn

When we have a certain quantity of water to employ in a shoc,
we may augment its force by setting it fall from a great height.

Thrô wch ye A B is ye top of a viuery vetained, c b is an hole of a foot squaure
y waters ought to go out, let E be ye middle of ye hole and ye height B E of 3
feet. It hath been shewn that ye shoc of ye water
thrô c b will sustain ye weight of a solid of water
having for base ye squaure of c b, and ye height
E B of 3 feet; that weight shall be therefore 3
times 70 pounds or 210 pounds. now let ye
waters be vetained so that ye height be 12 feet to
F, wch is ye middle of ye squaure hole G H, the
spout thrô F will go twice as swift as thrô E; it
therefore as ye diagonal of a squaure to its side
so is c b to G H, ye surface of that hole shall
be ye half of that of C D, and there will pass as
much water in ye same time because it will
go twice as swift and ye weight wch it will sustain
by its shoc shall be equall to ye weight of a
solid wch will have for base ye squaure of G H
and for height F B: but this last solid having its
height quadruple to ye first and to its base only double
it will weigh twice as much, and ye
spout G H will sustain a weight double to that wch
is sustained by ye spout c b whence is seen that to
turn a mill wch wants water, and hath but
half ye ordinary, by giving it a quadruple
depth ye same waters would turn it and make ye
same effect as if it had twice as much water.



The Third Part
of ye measure of Running and Spouting waters

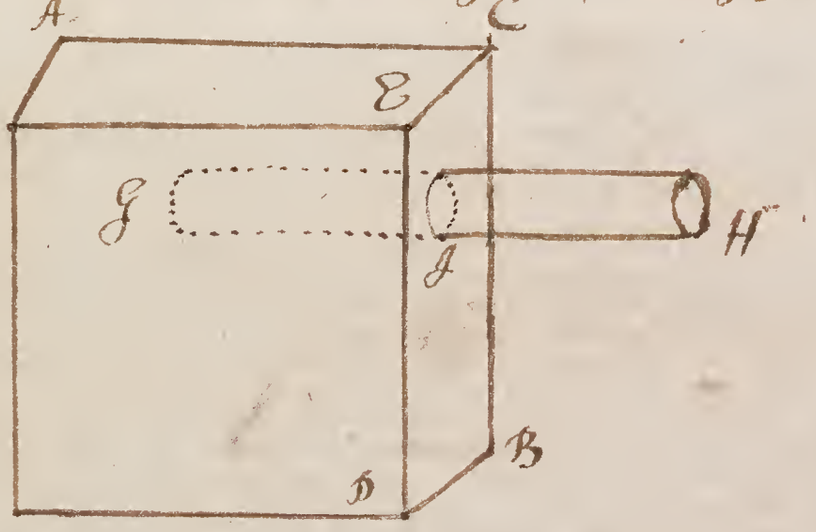
Discours I

Of ye inches and lines of water where with ye measure of running and spouting waters is expressed:

The makers of fountains measure ye quantity of water wch ye fountains give by ye inches and circular lines wch ye holes that they sink up in running through gently do superficially contain: but they have not well examined what proportion ye quantity of water those inches and circular lines give in a certain time, nor how high ye water ought to be above ye holes to furnish that running; which is notwithstanding necessary to know what makes an inch of water. How if ye water is kept at 6 lines above a circular hole of an inch, it would give much more water at that inch, than supposed it but one line, because as hath been shewn above in ye second part, a greater height of water makes ye spouts go swifter and ye running of ye waters thro' ye same hole is made according to ye proportion of ye swiftness with wch it goeth out; wch is proved in this sort.

A B is a vessel full of water, C E b B is one of ye sides of ye vessel where there is an hole I, G H is a cylinder of wood or of tin wch passeth thro' that hole with an uniform subtilness:

Now if we suppose that in one second it is advanced ye space of G H, it is manifest that in that time it will pass entirely and precisely ye hole I, if it



begins to enter thereby ye end H, and that it it goeth twice as slow it must employ 2 seconds to pass it entirely; and by consequent but half of it will pass in a second, and ye same in respect of other proportions:

We may draw ye same consequence in regard of spouts of water, viz. that there will pass twice as much water in ye same time thro' ye hole I, when it goeth twice as swift, and if in one minute it gives 10 pints in passing thro' that hole with a certain swiftness, it will give 30 in ye same time if it goeth 3 times as swift:

This being supposed it is evident that if there is two equal round holes in a reservatory one a foot below ye surface of ye water and ye other 4 foot,

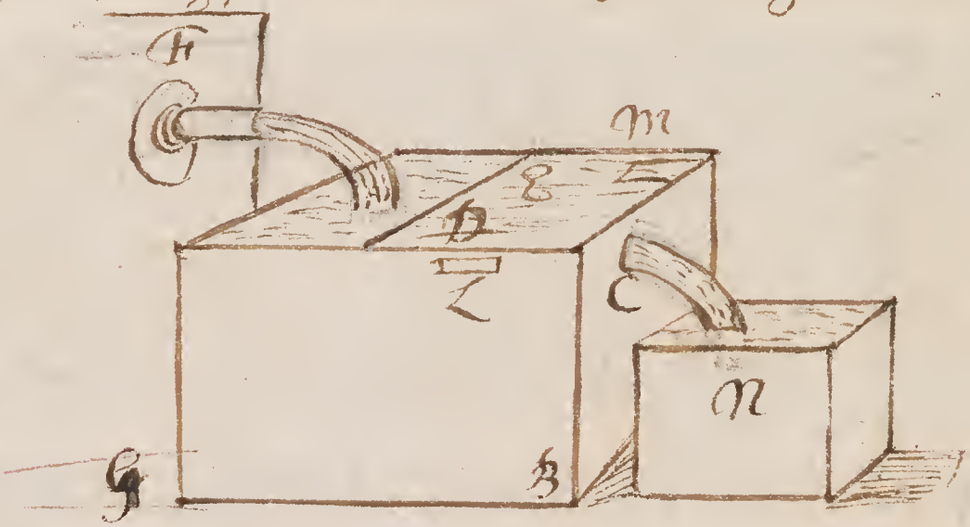
there will go out at that last twice as much water in ye same time since it hath been pierced ye water will go out at that last twice as fast as there ye other:

Whence is seen that to determine ye quantity of water wch ought to pass thrô a hole of an inch, & that perpendicular it is necessary to determine how high above ye circular inch ye surface of ye water wch furnisheth ye running ought to be.

Here is some experiments wch have been made to determine that height and ye quantity of water wch goeth out in a certain time:

First Experiment

We made use of a tinn vessel MB of 2 foot long, and 10 inches large, pierced in c with a square hole of about 16 lines large where there was affixed



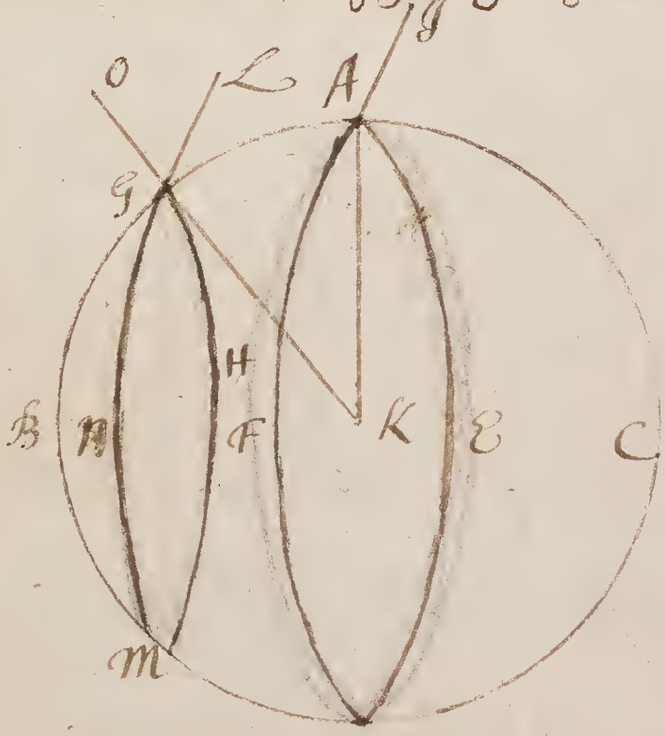
a small plate of copper pierced exactly of a circular figure of an inch dia= meter, this vessel being situated so that that hole was vertical, it was filled with water above ye hole stopping it with ye hand, and ye water was permitted to run from a vessel F wch was near it, in such quantity that passing all thrô ye circu= lar hole C ye upper surface of ye water of ye vessel might remain always about a line and a half higher than ye hole.

To make ye experiment right a hole must be made at ye side of ye vessel as in L a little higher than ye circular hole C to serve to discharge ye superabundant water, whilst ye height may be diminished as we please by means of a small plate of tinn wch is applyed there with a very viscous matter made of wax and turpentine. There was also applyed another small plate of tinn m to two inches at ye side of ye hole C and to a line higher by ye inn pan cell to ye water of ye vessel, so that when ye water was within ¼ as ¼ of a line thick we were assured that ye upper surface was near above a line higher than ye hole C and without this invention it would be very hard to be assured of it; because ye water makes ordinarily a small concave eleva= tion of about 2 lines high along ye body its brinches, which they are moistened wch hinders ye exact observing of ye height of ye surface of ye water in regard of the hole C. There was also in ye vessel a cross beam DE to receive ye froc of ye wa= ters wch should fall from ye other vessel into ye observatory that there be no waves made and that beam was distant about 9 inches from ye bottom of ye vessel and was pierced with many holes that ye water might pass it freely. this boring slightly glazed, ye hole was stopped with ye finger or otherwise and ye vessel was filled till ye water might pass thrô ye 4 lines above ye small plate m, and afterwards ye water was permitted to run at ye same time thrô ye hole and thrô ye other vessel, and if ye water of ye vessel remained at ye height of 3 or 4 lines or mounted higher, it was diminished a little by ye discharg= ing L, till very little water remained upon ye small plate m, as one fourth

of a Line thick, and that it remaining sensibly in that state a little vessel
N. to receive ye water wch should run thro ye hole C and after it had stayed 30 seconds
precisely it was suddainly drawn away and ye quantity of water wch was within
was measured:

To observe ye time of ye running there was made use of a pendulum
of fine thread charged at ye end with a ball of Lead of 9 lines diameter; ye length of
ye thread was 3 feet and 8 lines from ye point of suspension to ye centre of ye ball
ye pendulum beat seconds and we were assured of it by comparing it with a pen-
=dulum on clock after exact white marked ye seconds. ye same experiment was ma=
=ny times, and we found that there passed in 30 seconds thro that hole of an
inch, when ye upper surface of ye water of ye vessel was 7 Lines higher than ye
centre of ye hole; about 13 pints $\frac{3}{9}$ Paris measure, each pint weighing 2 pounds
less by 7 drachms.

In places nearer ye Line ye pendulum ought to be shorter because that
motion of ye surface of ye Earth in those places is greater than in France. Mr Richer
and Mr Cassini have made observations; ye first at ye Cayenne, where it was found
shorter by 1 $\frac{1}{4}$ Line, and ye other in ye Ile of Goree near ye same, where it ought
to be only 3 $\frac{1}{4}$ feet and $\frac{1}{2}$; this effect is demonstrated in this manner: AA B C repre=
=sents a meridian passing thro ye poles B C, and A E is ye æquinoctial Line & H
M n B C, [redacted] is ye parallel of Paris: Now suppose ye motion of ye Earth
from West to East, a stone wch should be in A would fly off from ye Earth in
a tangent; and because ye point A will go also swift, if ye motion towards ye centre
K did not augment its motion, it should be elongated from ye Earth according
to ye tangent Line A I; but that motion towards ye centre being stronger ye
stone shall not be elevated but it will nevertheless loose one part of its tendency
to motion towards K: ye same thing shall happen to a stone wch shall be at ye
point G, but its tendance to motion by ye tangent shall be much less strong,



because ye point A moves swifter than ye point G; therefore it will less hinder a
stone wch flyes from it towards K ye centre of ye Earth and likewise ye oblique
motion of ye small castle C m in regard of ye Line B K, may not diminish a
its attending towards ye centre: for ye oblique Line at C K being small
to go ye point L shall be less distant from K than ye point O, by reason two
causes ye stone being Looked in it will descend slower towards A than ye
stone in L will towards G. therefore ye motion of ye weight of a pendulum
shall be slower to ward A than G and by consequent to make their beatings

equall & thred of ye pendulum must be shaken towards F from towards G.

It is manifest that we cannot find precisely ye same quantity of water in all ye experiments and we shall always find some great difference how many cauils, viz. that it is difficult to begin to count ye seconds at ye same moment ye water begins to pass, that we cannot draw back ye vessel precisely when ye second is ended, that ye holes thro' wch ye water runs is not perfectly perpendicular, ye is not exactly an inch, or that ye thread of ye pendulum may a little shorten or lengthen it self during ye experiment or lastly that ye height of ye water is a little more or less than a line to ye place of ye small plate m, all wch things hinder ye precise exactness: but betwixt ye extremes and least is found this mesure of 13 pints $\frac{3}{4}$. If we would know ye water wch another circular hole gives as of 6 or 9 lines diameter, we might place them so that their centre may be 7 lines below ye surface of ye water of ye vessel, for ye height of each hole was placed at a like distance from ye surface, they would give much less water, than according to ye proportion of their greatness. But if they are so placed that ye centre of their holes might be at ye same distance from ye surface of ye water they give water neer according to that proportion as ye experiments wch have been made.

Experiment II

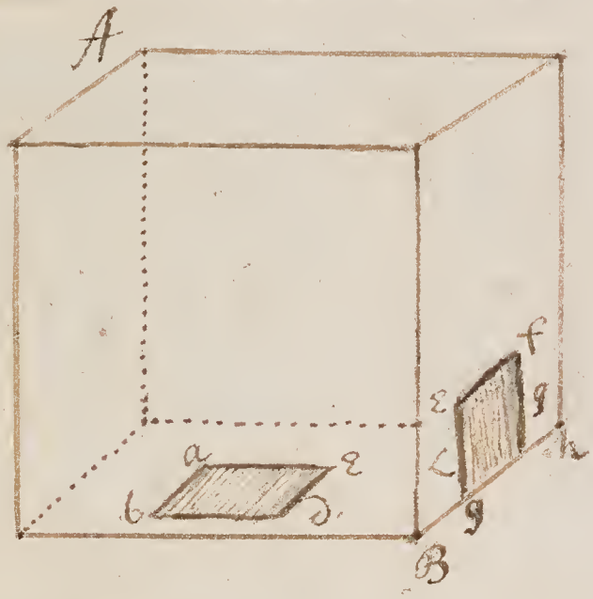
The water was many times made to run from ye same vessel thro' a hole of 6 lines whose centre was always at 7 lines distance from ye surface of ye water during ye whole running, and there was found betwixt ye least and ye least 15 pints in one minute, although ye surface of that hole was but $\frac{1}{4}$ of a circular line, and that according to that proportion ye ought to go out in one minute but ye fourth of 13 pints $\frac{3}{4}$ according to ye 4th rule of ye Equilibrium by ye Proc. that difference proceeds from many causes.

1° That although ye water of ye vessel was a line high above ye hole of an inch there remained near to ye hole but $\frac{1}{4}$ of a line during its whole running; wch might be easily known by a particular reflection of ye light wch was made in that place where ye water was lower than in ye rest of ye vessel, and that depression was made because that ye water wch succeeds that wch runs, ought to come from ye neighbouring parts, as hath been explained above, and there being very little elevated near ye hole, it must be almost at rest to pass, wch diminisheth ye force of ye pressure of ye water and retards ye swiftness of its running:

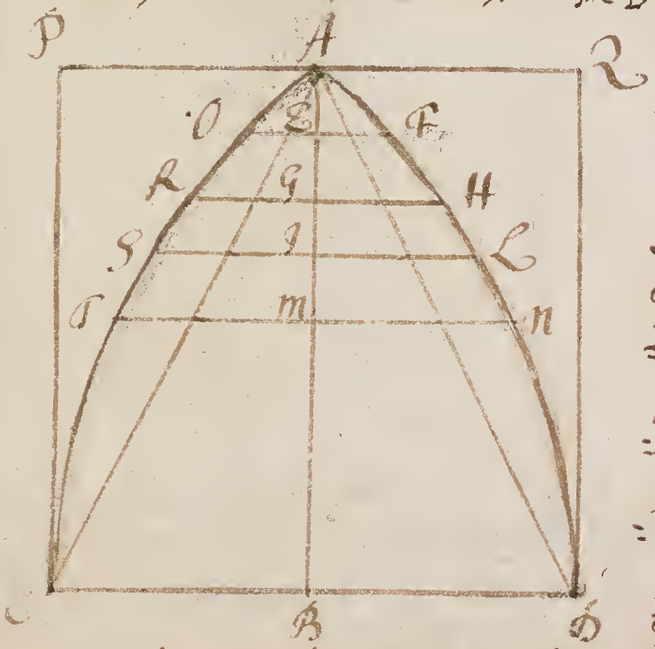
2° That there coming little water from on high it must necessarily be that it comes from far to succeed that wch runs, wch also retards its swiftness: but ye same thing doth not happen to a hole of 6 lines because that not being to give but $\frac{1}{4}$ as much water as ye inch, and its hole lying surmounted by 4 lines thickness of water there is not made any considerable depression; and by consequence ye water is pressed by these 4 entire lines besides that ye water will ought to succeed that wch runs doth not come so far as when that is an inch, and also that ye top of ye water wch is directly above ye hole of an inch, was 7 lines above its centre, it would be necessary it should be in ye vessel near 8 lines:

There is yet another cause wch is that ye swiftness of ye running being in a subduple proportion of ye height of ye waters, as hath been said, if there is a vessel as A B pierced at ye bottom with an horizontal hole as a b c d and with another vertical e f g h, equal one to ye other, and that ye water be elevated in ye vessel to ye precise height of e f there ought to go out at that vertical hole half $\frac{1}{2}$ as much water as there will go out thro' that wch is at ye bottom of ye vessel at ye same time if ye water is maintained at ye same height e f wch is proved in this manner:

The water wch goeth thro' ye hole of ye vertical hole e h hath its swiftness in regard of that wch goeth thro' I in a subduple proportion of ye height e g to ye height e I, and ye same in regard of all ye Horizontall



divisions wch may be made in ꝺ ſpace et g h at equal diſtances; whence it
follows that it ꝺ ſhortneſs of ꝺ walls of ꝺ firſt diviſion towards ꝺ top is 1 ovr 1
that of ꝺ ſecond will be R2, that of 3 R3 &c ſuch is ꝺ ſame propoſition as ꝺ
ordinates of a parabola Let therefore t c b be a parabola whoſe baſe c b may be ꝺ
of ꝺ rectangle c B P Q, and let ꝺ axis
t B be diviꝺed into many equall parts
by ꝺ lines E F, G H, I L, M N &c paral=
=lel to B B theſe lines ſhall be ꝺ ordinates.
now by ꝺ property of that figure ꝺ ſquares
of ꝺ ordinates are to one another as ꝺ
ſegments of ꝺ correſponding axis t E,
t G, t I, t M, &c and theſe ſegments are
one to ꝺ other as ꝺ numbers 1, 2, 3, 4
&c, therefore ꝺ ſquares ſhall be alſo one
to ꝺ other as 1, 2, 3, 4 &c, and by conſe=
=quence ꝺ lines O E, F R, G H, S I L, T
M N, ſhall be one to another as R1, R2
R3, R4 &c. now if we take all ꝺ poſſi=
=ble lines wch can be drawn parallel to B
b infinite in number for ꝺ parabola,
they will be to an infinite lines wch com=
=poſe ꝺ rectangle c b t as ꝺ parabola is
to ꝺ rectangle, but ꝺ triangle c Q b,
wch is ꝺ half of ꝺ rectangle P Q c b, is
ꝺ of ꝺ parabola as it hath been proved
by Archimides; therefore if ꝺ triangle is 3
4, therefore it is $\frac{2}{3}$ of ꝺ rectangle.



ꝺ rectangle ſhall be 6 and ꝺ parabola

Thoſe wch do not know ꝺ properties of ꝺ parabola may know
that both by calculation any neaꝛ, by taking ꝺ ordꝛ of theſe ordinates wᵗ numbers
and extracting theiꝛ ſquaꝛe roots by Archimides as in ꝺ following table, where ꝺ firſt
ranck ſhews ꝺ entire numbers, ꝺ ſecond, ꝺ ſquaꝛe ꝺ ſecond ꝺ ſquaꝛe ꝺ thiꝛd, ꝺ ſquaꝛe. &c

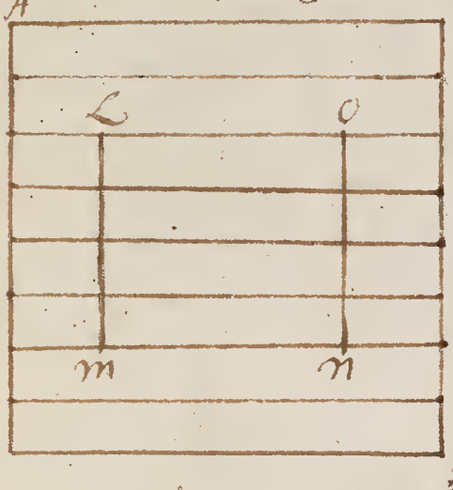
	Numb	Primos	Seconds	Thirds
R 1	1			
R 2	1	4	1	4 1/2
R 3	1	7	3	
R 4	2			
R 5	2	2	3	6
R 6	2	4	4	9
R 7	2	6	4	5
R 8	2	8	2	0
R 9	3			
R 10	3	1	6	2
R 11	3	3	1	6
R 12	3	4	6	2
R 13	3	6	0	5
R 14	3	7	4	3
R 15	3	8	7	2
R 16	4			
R 17	4	1	2	3
R 18	4	2	4	2 8
R 19	4	3	5	
R 20	4	4	7	2
R 21	4	5	8	2
R 22	4	6	9	1
R 23	4	7	9	2
R 24	4	8	9	9

Now if we take ye Summ of ye 12 first numbers, it is somthing more than 29 and 12 times ye 12th number viz 3 4 8 2 gives a product somthing more then 415 and by consequence that Summ wch is ye parabola is greater than 2/3 of ye product wch is ye rectangle: but if we take ye 24 numbers we shall find somthing less than 79 for ye parabola, and ye product of ye last 48 29 by 24 is somthing more than 117 whereof ye 2/3 is 78 and to ye Summ of ye 24 numbers doth not differ from 2/3 of ye product but about an vnite and it approacheth nearer that when we take ye 12 first numbers, and is we continue to encrease ye talle by a greater number of divisions, ye difference of that Summ and of product will diminish always, so that we may judge it would at last come to be precisely 2/3

We see also that if we take ye 6 numbers from ye middle of twelve, they do fulfill ye Summ of 3 first and ye 3 last to gether, and that ye Summ of ye 6 first and ye 6 last of 24 shall be less than ye Summ of 12 of ye middle wch ought necessarily to happen and may be demonstrated in this manner:

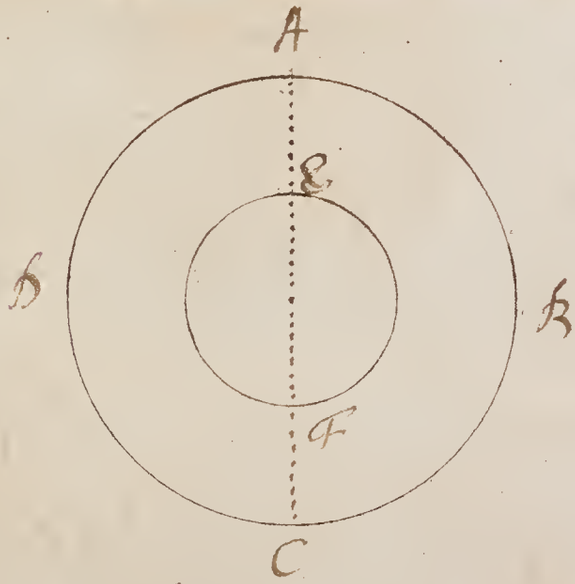
The extremes of ye squares of numbers wch are in an arithmeticall

progression are greater than those of ye middle numbers as ye squares of 2 and and of 8, wch make 68, are greater than 52 the squares of 4 and 6,



the sum of ye squares of A and b, or ye excess is produced from ye square of ye difference of ye numbers of ye progression: now since ye squares of ye odd nalls of a Parabola are in an arithmetical progression and that of ye two together are equall to those of ye middle it follows that their words are not in an arithmetical progression and that of 1 and 3 together are less than those of ye middle: for if they were equal ye squares of ye extremes would be greater and because of ye running of ye water it follows their powers. It follows that if there is 8 divisions of ye square AB C b ye 4 of ye middle wch are of the = angle E F g H, give more water than ye 4 extreams wch is ye half of that rectangle and ye fourth of ye great square will give more than $\frac{1}{4}$ of ye water wch ye whole square gives:

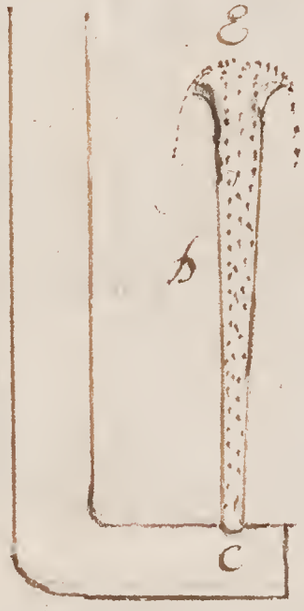
It happens therefore for this cause and for that of ye difficulty of running through ye hole of 6 lines square having 4 lines of water above gives more than ye length of that wch a square hole gives surmounted only by a line of water. Near ye hole it is true that there is something less willing in pro= =portion against ye sides of a great hole than of a small wch gives a little ad= =vantage to ye great: but ye other causes being more considerable there ought to go out always more water in proportion thro' ye lesser holes with 2 lines diameter than thro' ye great; wch have agreed to experience.



The same thing ought to happen near, and for ye same causes to circular holes, that is that if we take in ye great circle AB C b, ye small inward and concentrick E F: wch diameter may be equal to ye half of A C; and by consequence equall to ye 4th of that of ye great circle, there will pass thro' that hole something more than $\frac{1}{4}$ of that wch will pass thro' ye entire hole AB C b wch hath been found con= =formable to all ye experiments in ye small elevations of water above ye holes, ye great circle having given always near 13 pints in one minute. and ye small 6 demi septiers as hath been said

It happens also that if ye small hole thro' wch ye water passes is situated horizontally at ye bottom of a vessel, so that ye water runs perpendicularly from above downwards there will run more in ye same time than if in another vessel ye hole was vertical and ye spout horizontal although ye surface of ye water was as much elevated above ye centre of this last as of ye other, wch proceeds from hence that ye water going from above downwards, accelerates its swiftness and because of its velocity draws further ye parts wch is next it, and also those wch are near ye hole within ye reservatory: and there will go out less yet from a like hole if it is disposed to spout ye water perpendicularly from

below upwards thro ye hole c since ye water goeth swifter in b than in E and so that above is always a little retarded.



It is found by many experiments that if there should go out 15 pints in a certain time thro a spout whose hole is 4 lines wch runs from above downwards there would go out but 14 when it was made to spout perpendicularly from below upwards, altho' surmounted by a parallel height of water, and that happens parallelly in ye moderate heights of ye reservatorys: for it they are of 20 or 30 feet ye difference is less sensible because that ye water goeth so swift from above downwards in its beginning that it makes not any considerable accretion in ye water of ye spout wch is below ye hole; because that a drop of water falling acquires but little more swiftness than that of the water wch goeth out thro a hole when ye surface of ye water is 30 feet above, as hath been explained in ye end of ye 3d edition of ye Fragile of ye shock of bodys:

By these reasons and experiments it is seen that it is difficult to determine wthout an inch of water is; and because that ye diversity of spouts of water are made ordinarily thro great heights of reservatorys and thro small holes of tin staves it might how ye matt part to be regulated by experiments of mean holes as of 6 lines as of 4 lines, then by these of an inch entire. I have took a middle these experiments of different holes, and as much for ye facility of calculation, as to have a certain measure, and to take away all difficulty.

I call therefore an inch of water ye water wch running during the space of one minute gives 14 pints Paris measure, of those wch pass ye brims a little and wch weighs two pounds each. Ye hole of an inch will give that quantity if ye water is one line above ye hole: but it must be two lines higher in ye vessel to ye end it may be precisely a line high above ye hole. For holes of 6 lines it will suffice that ye water of ye vessel be 4 lines above ye centre.

That measure so determined is very commodious for calculation, since that in space of one hour ye inch will give 3 muids of paris, and in 24 hours muids, those wch know ye pound less by 7 drachms it would give but 66 muids $+\frac{63}{72}$ in 24 hours, and those fractions would give much trouble when we would know ye different dispensings of water thro different sizes placed at ye bottom of different heights of ye reservatorys. To confirm this rule ye following experiment was made.

Experiment III

We took a square vessel containing a cubic foot to ye 12th inch; but ye last division was of 2 lines from ye bottom to ye top of ye vessel. Ye water was made to run in by ye means of a vessel, where there was a hole of a circular inch, as hath been described above, ye small plate m was two lines higher than ye top of ye hole, so that near ye top of that hole ye surface of ye water would remain one line high when it was 2 lines high in ye rest of ye vessel. This cubic foot was filled to ye 12th inch by running water in ye space of 2 minutes and $\frac{1}{2}$: whence it followed that a circular hole so disposed gives 14 pints or 28 pounds of water in a minute, since it give 35 pints in 2 minutes and $\frac{1}{2}$

By this means is easily known ye inches of water wch a mean fountain gives, or a running rivolet, for we put but receive ye water in some vessel or place that we can measure and wch holds ye water, and counting what number of minutes or seconds we we place; for example if we have received in a vessel 7 pints in 30 seconds we may say that that running water is of an inch, if it hath given 21 pints of 3 inches, and so in other proportions.

Discours II

of the measure of spouting waters according to ye different heights of ye reservatorys.

It hath been proved that ye quantity of water wch goeth out thrô equal holes made at ye bottom of reservatorys of different heights are one to another in ye subduple proportion of ye heights; but to confirm that more by experiments I have made many with great exactness whereof these are the principall.

Experiment I

For the expence of spouts at the bottom of reservatorys of different heights.

A hole of 6 lines having its centre at 39 lines below ye superficies of ye water of ye vessel, gave in one minute 85 pints of those wch weigh 2 pounds less by 7 graines; ye water did run horizontally, as in ye experiment above where ye same hole had its centre 7 lines below ye superficies of ye water of ye vessel and gave 15 demiseptiers in a minute to compare these 2 experiments according to ye rule we must take a mean proportional number between 7 and 39 wch is 16½ near; and to 3 numbers 7, 16½ and 15 find ye 4th proportional, wch is 35¾ near. 35¾ demiseptiers make 8⅝ pints, and by consequence ye expences of ye water have been according to ye subduple proportion of ye heights of ye reservatorys.

Experiment II

A pipe having its height 16 inches gave thrô an hole of 3 lines placed at ye bottom thereof wch ye water did run perpendicularly 25 pints and about 2 spoonfulls in 30 seconds maintaining ye water always at ye height of 16 inches; there was placed at ye bottom of another pipe a little plate where ye hole was of 3 lines; that second pipe had ye height of its water of 64 inches wch is a quadruple of ye former of 16 inches, nicely consequence it ought to give a double of 2 pints½ and 2 spoonfulls, keeping ye water always at that height of 64 inches, wch hath been proved by experience, for there went out of this pipe 5 pints and about 4 or 5 spoonfulls of water in ye same time of 30 seconds: this experiment was made with great care and repeated times. moreover we made some other like experiments with about 4 foot below upwards to 6 or 6 feet high, and we always found ye same subduple proportion of ye heights of ye reservatorys. we may therefore take for time ye following rule.

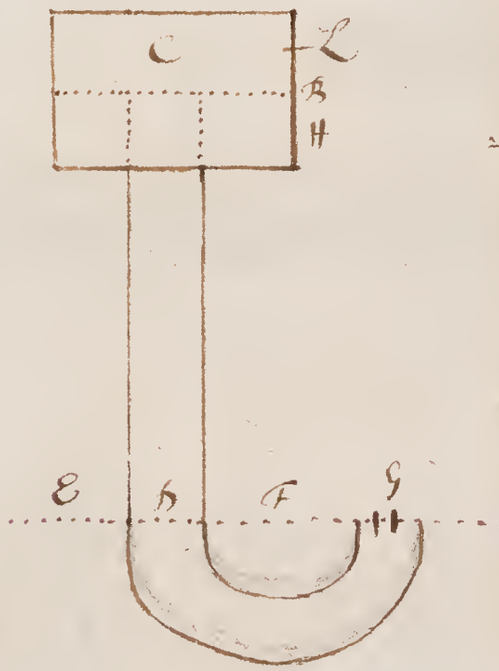
Rule

for ye measure of spouts.

The spouts of water wch go out thrô equal holes at ye bottom of different elevations of ye reservatorys, have their waters in respect one of another according to a subduple proportion of ye heights of ye upper superficies of ye water of ye reservatorys. As to find out easily by calculation all ye quantities of water wch reservatorys give of what height soever they are, I made choice of a mean height to wch we might easily reduce all ye others; that height is 13 feet and I have found by many exact experiments that a round hole of 3 lines diameter being 13 feet below ye surface of ye water of a large pipe, did give an inch, i.e. there went out in ye space of one minute 14 pints Paris measure, of those wch weigh 2 pounds and whereof 35 make a cubic foot.

The experiments were made in this manner. A pipe was crooked below, and had a reservatory C wch held about 20 pints, a hole of 3 lines was at ye point E its diameter was such that of 2 points of a compass whereof ye

was 3 lines first, might enter in precisely without wetting upon ye sides and without wetting upon ye sides and without leaving any voide intervall. E G F is an horizontall line wherein a hole C was, it was 13 foot from B to C where ye surface of ye water was in ye reservatory there was measured 14 pints in 3 gallons, and it was poured to be poured so that ye water might arrange always at one ye augre B made at ye side of ye reservatory at ye height C, and when in pouring the water was stopped a line, it was poured further till it might pass a mark near as much the hole C was stopped with a finger, and a pendulum that beat seconds was put into motion: he wch held ye hole stopped began to open it at ye beginning of a second and counted 3 seconds following during wch 3 seconds that wch poured ye water took heed that when he began to count ye water was precisely at ye height of ye mark, and they poured in their 14 pints between 0, and ye 3d second. I made this experiment another way to avoid ye doubt of ye indequality of ye water wch was poured: there was put 2 pints into ye reservatory from a mark as A to another as B in equall distance from ye point B, ye hole was stopped with ones finger till ye seconds began to be counted, and ye height of ye water was observed to be at ye point L.



It is eazy to judge that during that running there would go out sensibly as much water as if it remained always at a mean height B of 13 foot, because if it went lower being in A it went also slower being in H in ye same proportion.

The experiments wch I made at great heights as 35 foot would give about $\frac{1}{17}$ or $\frac{1}{18}$ less than according to a hydrostaticall proportion of 13 foot to those heights, and those wch I made at a height of 6 or 7 foot would give something more, wch proceeds from ye greater or lesser resistance of ye air but as these differences of 3 lines and of 2 greater or lesser resistance of ye air but as these differences are inconsiderable, we may make calculations precisely according to that rule of hydrostaticall proportion from there is a table of ye quantity of water wch ye reservatorys of divers weight do give unto 52 foot thro an (aperture fole) of 3 lines.

A Table of the expence of water at different Elevations of ye Reservatorys upon 3 lines (aperture) in one minute

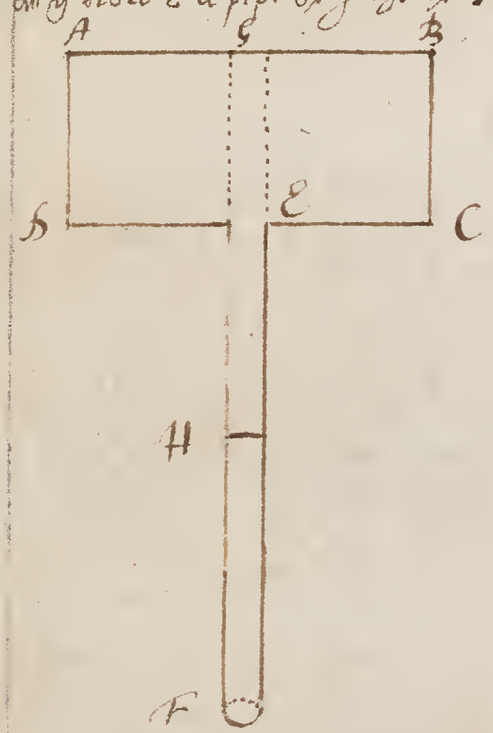
Heights of the Reservatorys	Expence of the water
6 foot	9 pints $\frac{1}{2}$
9 foot	11 pints $\frac{2}{3}$
13 foot	14 pints
15 foot	16 pints $\frac{1}{2}$
25 foot	19 pints $\frac{1}{3}$
30 foot	21 pints $\frac{1}{3}$
40 foot	24 pints $\frac{1}{2}$
52 foot	28 pints

This is ye way to calculate; Let 2 feet be ye height of ye reservatorys, ye product of

2 by 13 is 26 whose Sqraue root is $5\frac{1}{10}$ neqr as 13 to $5\frac{1}{10}$ so is 14 pints to $5\frac{1}{2}$ neqr: whence we conclude that a reservatory of 2 feet high thro-three lines will give $5\frac{1}{2}$ pints in a minute.

If ye height was 45 feet we must in a minute ye Sqraue root of 585 ye prodnct of 13 by 45, that root is $24\frac{3}{5}$ neqr; wherefore as 13 to $24\frac{3}{5}$ so 14 to 26 neqr, whence is known that a reservatory of 45 feet would give 26 pints in a minute thro a hole of 63 lines.

When we apply a long straight pipe to a Large reservatory and that that pipe is perpendicular it gives more water than if ye pipe was not there and that there was only at ye bottom of ye reservatory a hole eqnal to ye hole of ye pipe. Heare are some experiments wch I made of it.



A B C D is a reservatory of a foot Large and height, there is put all ye hole E a pipe of glass of 3 feet 3 lines Large at ye top and 3 lines and $\frac{1}{2}$ at ye bottom towards F it there hath been but a hole of 3 lines in E without ye pipe it would have given in 60 seconds something left than 4 pints, according to ye rules above, and if it had been equally large thro out as at ye height of E being 4 foot and ye hole of 3 lines it would have given about 8 pints by ye same rules. But ye pipe being there it did give but about ye mean proportional between 4 pints and $8\frac{1}{2}$ pints: ye reason that it gives more than three 3 lines in E proceeds from ye accelleration wch ye water makes running thro ye pipe, wch is increased according to ye running, if there was nothing but ye pipe, but it is restrained by that wch is in ye reservatory wch diminisheth that acceleration, because it cannot be separated from it, but also that in ye pipe makes that ye reservatory follows it with more than it would if ye pipe was not fitted to it, and by that means makes a mean fluxion of running wch changes according to ye length and Largeness of ye small pipes.

I have observed in these experiments that ye pipe being unequally Large at ye two ends as in that wch was of 3 Lines at one end and $3\frac{1}{2}$ at ye other, gave always ye same quantity, that is which was put in ye hole E. water is avoided in ye same time wholly being wch proceeds from hence that all ye it from one end to ye other:

I made another like experiment there was fitted a pipe of 6 feet and an inch Largeness to ye hole E of a cubic foot, wch having been filled with water ye pipe was void in 37 seconds and having cut ye pipe thro ye middle A it will be void in 45 and cutting it thro at top E it will be void in 95; whence is seen that ye length of ye pipe gives greater acceleration:

Another vessel whereof ye water was 4 inches above ye hole E of 4 lines: where is ye pipe E F, gave when it was 2 foot height $12\frac{1}{2}$ inch measures whereof if it had given but $8\frac{1}{2}$ at ye height of 4 inches. and if ye vessel had been to F there was give $18\frac{1}{2}$; so it is a mean proportional wch proceeds from ye swiftness of ye water wch always tries ye pipe, and differs swifter thro E, but not so swift as if ye vessel had 24 inches height: we found there $8\frac{1}{2}$ ye pipe being but one inch high because it made Little acceleration: another pipe of 4 feet made almost ye same effect if had 4 Lines at one end and $4\frac{1}{2}$ at ye other, it was put to the hole E in both these positions, it gave ye same quantity of water, but that it seemed that ye 4 Lines being in E and ye $4\frac{1}{2}$ in F there went out 3 or 4 spoonfull more straight:

But having applied a pipe of 2 feet $\frac{1}{2}$ long and it hole E of a Lines, there went not out $\frac{1}{2}$ more when ye pipe was at that Length than when it was only one inch; wch proceeds from ye rubbing along ye straight pipe wch hinders ye water from accelerating its swiftness in falling

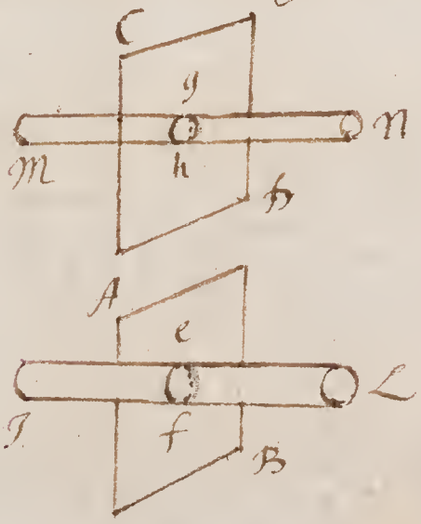
Discours III

Of the measure of spouts by the (cairystrews) filling of different holes

wch spout with equal swiftness thrô different holes make an equilibrium of their proportion wch weight wch are one to y other in a hydrostatic proportion of y diameters of y holes: we may say y same in respect of y expence of water wch goeth thrô different holes at y bottom of vessels of equal heights viz that they expend their waters in a like simple proportion of y diameters of y holes, it is demonstrated in this sort:

Demonstration.

A B is a plain pierced with a round hole E F. c b is another plain pierced with another hole gh smaller than y other, y L is a cylinder passing entirely thrô in a certain time as of 2 seconds according to an unitown swiftness: m n another cylinder of same length, but whose base is smaller, wch passeth also entirely thrô y hole gh in y same time of 2 seconds; it is manifest that y diameter E F of y cylinder L wch is y same with that of y hole is double y diameter gh of y great cylinder shall be 4 times y other since they are one to y other as their bases, whereof each is supposed equal to y hole thrô wch it passeth: now since they go with y same swiftness, when y half of y great cylinder shall be passed y half of y little one shall be passed also, and that wch shall be passed of each shall be always in y same proportion of 4 to 1. therefore if we suppose these cylinders to be spouts of waters wch go with y same swiftness thrô wch always pass in y same time 4 times as much water thrô y great hole as thrô the small which is y double proportion of the diameters of y holes, and y same in respect of other proportions, to confirm this rule we made y following experiments:



Experiment I

A reservatory having 12 feet 4 inches elevation gave thrô a hole of 3 lines exactly measured 14 pints in 61½ seconds keeping it full and thrô a hole of 6 lines exactly measured gave y same quantity of water in 15½ seconds; wch is near according to y double proportion of y diameters: for thrô was given about 56½ pints in y time of 62 seconds

Experiment II

A reservatory of 24 feet 5 inches high gave thrô y same hole of 3 lines 14 pints in 44 seconds ½ and another time in 45; and y hole of 6 lines gave them in 11½ near and having repeated y experiment it gave them in 11 seconds precisely. by these 2 experiments and many others like wch were made in moderate heights from 5 to 27 feet, we found that different holes would give always waters equally and near according to y proportion of their quadrats and that we may follow this rule.

Rule

For the expence of spouts of water of different holes placed below reservatorys equally high, give their waters according to a double proportion of y holes.

A Table of the Expence of water in one minute through different wounds (sightsins) the water of a reservatory being 13 foot high.

Diameters		Expence
thro' a passage of	1 line	1 pint $\frac{10}{24}$
thro'	2 lines	6 pints $\frac{21}{24}$
thro'	3 lines	14 pints
thro'	4 lines	almost 25 pints
	5 lines	39 pints
	6 lines	56 pints
	7 lines	76 $\frac{1}{4}$
	8 lines	110 $\frac{2}{3}$
	9 lines	136
	12 lines	224 pints

If we would observe ye calculation of inches we shall find that a hole of 3 lines will give an inch that of 6 lines 4 inches, and that of 12 lines 16 inches. There is some cause wch hinders ye exactness of these rules, so that verie often great holes give a little more in proportion than ye small ones and some times a little more than according to a fulduple proportion and sometimes a little less. I have made ye following experiments.

Experiment III

I took a pipe of half a foot diameter and about 6 foot high having a reservatory at ye top wch did contain about 12 pints; I put at ye bottom of ye same plate pierced with an hole of 12 lines wch served for first experiments, and another of 4 lines in ye same bottom; ye hole of 12 lines was distant about an inch from ye edge of ye box, and that of 4 lines also an inch; we put a great quitter below wch had a separation wch divided it imegually, it was filled so that ye water wch ran thro' ye 4 lines might enter into a small separation and that wch ran thro' ye 12 in ye other; ye pipe being full of 2 holes were permitted to run at ye same time, and ye water was drawn away on a hidden, so that ye two holes might erase to run equally at ye same moment, we always found that ye great hole wch according to ye second rule ought to give 9 times as much as the small gave but 8 times as much, and 8 times and a little more in other experiments. ye cause of this effect is ye same as we have spoken above, viz ye water runs not so easily thro' ye great hole as thro' ye small, so ye great one being to give 9 times as much water it is necessary that such should succeed what comes from near a foot circumference, and ye distance on one side of ye pipe was but an inch and ye shortest distance 4 inches; wch would retard ye running, ye circumference not being able to come so swift as was necessary; whereas in ye small hole ye distance of an inch on all sides was sufficient to furnish sufficiently enough for ye running; and that difference made a difference in ye quantity of water run out as in ye experiment of an inch where ye centre was lower than ye surface of ye water 7 lines wch gave but 12 $\frac{3}{4}$ pints whereas ye hole of 6 lines gave $\frac{1}{4}$ of 15 pints ye centre being ye same distance of 7 lines from ye upper surface of ye water.

Experiment IV

To take away this difficulty of ye running many experiments were made in a tub whose bottom was large enough to place ye hole of 12 lines a foot from ye greatest side, and ye small hole was placed more than a foot distance from ye great one. ye experiment being made with ye same vessel where there was a separation we always found that ye great hole gave less than 9 times ye small one; for it wanted sometimes $\frac{1}{19}$, and sometimes 20,

is that if ye small one gave half a pint paris measure ye great one gave 8 1/2 pints or 8 3/5, we measured exactly again ye two holes and found that that of 12 lines was ~~[illegible]~~ a little stronger in proportion than that of 6 lines, at least we were assured that it was not weaker, and by consequence that ye jetts of ye quantity of water it ought to give, do not proceed from that cause. In ye experiments wch were made separately with different holes ye great holes gave ordinarily more in proportion than ye small there are three causes wch may contribute to this effect.

The first that there is more rubbing in proportion in ye small holes than in ye great: for ye circumference of different holes are one to ye other in proportion of their diameters, whereas ye water they give is in a double proportion of the same diameters: now it we suppose ye water by its rise of it sticks a little to ye sides of ye holes, it will necessarily diminish for that reason a small part of ye largeness of its diameters. For example at a hole of 3 lines it may diminish 1/10 of a line throughout at a hole of 6 lines altho ye semence of 6 be quadruple of semence of 3 and that ye round holes are one to another as ye squares whose sides are equal to ye diameters of ye circles, yet ye circumference of ye hole of 6 lines diameter, shall be only double to that wch is 3 lines; and therefore it will diminish but 1/20 or 1/10 for that hindrance whence we see that ye spouts of ye great holes are not to be added and hindred as ye small, and give more water in proportion of their diameters:

The second cause is that a small stream of water finds more resistance in ye air as it goes out than a great spout as it happens to small balls of lead wch go not so far as large ones, altho they go out of ye same mus=ket in ye same time.

The third cause is ye greater shoc of ye water wch is poured to maintain ye running thro great holes. how to keep ye reservatory full whereof there water goes out tell at 4 lines, viz. is sufficient to pour ye water gently with a small vessel; but when ye spout is 12 lines large, ye water must be poured with a full pail, and with great swiftness wch gives it an impression to ye water that makes it go further than if it had only its own weight to push it; we made an experiment placing horizontally an hole of an inch height and 4 inches long, how it gave in 36 1/2 seconds a quantity with it ought not to give but in 1/4 of 15 seconds, viz in 38 1/2 wch did proceed from hence that ye water was poured with great force to maintain that wch went out, and also when we did not maintain ye reservatory full of wa=ter 15 seconds swifter thro a pipe of 3 or 4 inches large when ye spout is gross than when it is small, wch necessarily augments ye swiftness of its going out. these 3 causes joyned together are sometimes a little stronger than the difficulty of running along and sometimes but equall, when ye experiments are made separately thro different holes.

Here are some experiments I have make with a hole of 3 lines and one of 6 lines.

Experiment I

The hole of 3 lines having its reservatory 5 1/2 foot high gave 14 pints, of 2 pound weight in 93 seconds, and ye hole of 6 lines gave them in 23 seconds instead of 23 1/4

Experiment II

A reservatory being at 24 foot and a little more gave thro a hole of 3 lines 14 pints in 44 seconds and 1/2 and thro 6 lines in 11 seconds maintaining ye height of ye water in ye reservatory.

Experiment III

From ye height of 12 1/3 foot ye hole of 3 lines 14 mean pints in 61 seconds 1/2 keeping it full, and thro a hole of 6 lines it was given in 15 1/2.

Experiment IV

There was put a mark in ye reservatory wch was at ye top of ye pipe higher than that wch marked ye 12 feet 4 inches, and another lower at an equall distance, that permitting ye water to run from ye upper mark to ye lower, it might produce the same effect as if it was always kept full of 12 feet 4 inches; there was 13 1/2 pints in the reservatory from the upper mark to the lower; these were run out thro 3 lines in 58 seconds, and through 6 in 15 instead of 14 1/4

Experiment V

The reservatory being at 24 feet 3 inches and at ye middle mark there was given thro 3 Lines 14 pints in 4 4/5 seconds and thro 5 Lines in 12 ½ mean, and recruiting ye 13 ½ pints to run thro ye middle mark it emptyed 42 seconds thro ye 3 Lines and 10 ½ thro ye 6 Lines: this last experiment confirms ye proportions equall as well as ye second.

We found neare ye same in a reservatory of 35 feet.

By these different experiments is seen that we may follow ye second rule without any considerable error, and that ye contrary causes, make always a compensation just enough when ye experiments are made.

In respect of ye fifth rule upon proportion of ye heights of ye reservatorys there are two causes wch diminish it any thing wch augment it;

Those wch diminish it are that ye upper parts move in proportion with greater swiftness than to a small, and that ye rubbing is greater against ye sides of ye Calingtags.

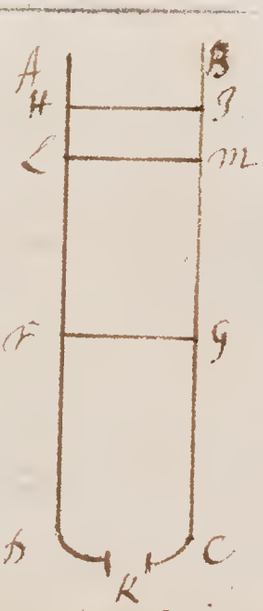
Those wch augment it are ye same wch cause ye great holes sometimes to give more water in proportion than ye small viz that we might pour in water with greater force to maintain ye reservatorys fuller in a great height than in a small, and that ye water descends swifter when we permitt it run:

These causes do neare enough compensate one ye other: but it happens ordinarily that there is less than a little less than ye double proportion in ye great heights: but when ye experiments are made in ye same bottom of ye reservatorys in the same time, ye great holes always give less in proportion than ye small ones:

Torricelli hath demonstrated in a small tract wch he made of ye motion of ye water, that if there is a reservatory A B c b pierced at ye bottom

in c with a small hole of 4 or 5 Lines, and that ye water being to ye Line A B, it may run out in 10 minutes without adding any thing to it, it will pass unequal spaces in equall times, so that if we divide ye Line B c into 100 equal parts it will require in ye first minute 19 of these parts in ye second 17 in ye 3 15 &c according to ye numbers unto a unity, so that ye last part shall be voided in ye last of ye 10 minutes. The reason of this effect is framed upon ye first rule explained above that ye swiftnesses of running waters are in a subdu-ple proportion of ye heights, and ye consequence are one to ye other heights, as ye ordinates of a parabola A c beginning at ye greatest A B and ending at ye point C wch causes ye spaces passed into ye same time by ye surface of ye water A B to be as the odd numbers following one ye other beginning at ye greatest.

From thence is drawn a consequence that if we measure ye quantity of ye water wch is contained in ye reservatory to ye Line A B, and that it is run out in 10 minutes, there will go out thrice as much in ye same time, if we allways maintain ye reservatory full to ye height A B, wch proceeds from thence that if a drop of water was fallen in a certain time from B to C and that it contained its swiftness acquired at ye point C without augmenting or diminishing it would pass in ye same time a space double to B C: now ye water wch goeth out hath always ye beginning thro ye hole c half a swiftness equal to that ye falling drop would have acquired at ye point C, and all ye water wch goeth out hath always ye same swiftness if ye reservatory continue with full there will go out thrice as much in ye 10 minutes as there doth remaining it to run without adding any thing to it, and in 5 minutes as much as it contains.



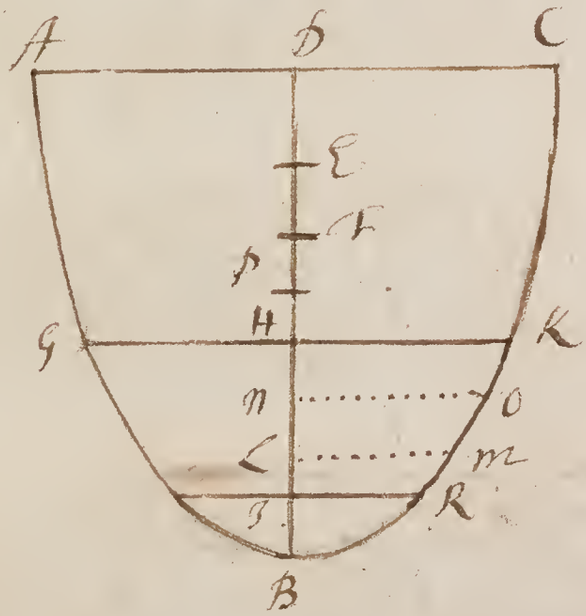
But ye same thing doth not happen when ye pipe is but ½ foot Longe and 2 or 3 feet high as ye pipe A B C D having a hole K of 6 lines ye diameter of ye water wch descends while it runs out giues an impulse to that wch goeth out, wch ioyned to ye weight of ye water makes it go swifter than it makes it when it descends slowly ye pipe being very Longe I have many times found that if ye water would run out entirely from such a pipe of water in 4 minutes that there would run out 1½ when it was kept full of going out in 2 minutes, and yt that pipe might contain 24 pints and that they would run out in 4 minutes there would go out but 10 keeping it full in ye space of 2 minuts and 24 seconds: that perfect proceeds from science that ye swift is more retarded by ye rubbing and by ye resistance of ye ayr in ye vessel when it is swift than when it is slow as is explained above, and so it is always equally retarded by these 2 causes when ye pipe is maintained full; but it is less when ye water is but at ye height L M, and yet less when it is descended to F G. It is true that if ye water turns round as it sometimes happens then ye running out shall be retarded, and may ye contrary effect of acceleration:

This turning round is made when ye hole is not in ye same plane, and that ye running water goeth out a little a cross in one place

In ye last experiment I made of this matter ye water was 10 inches high above a hole of 4 lines wch was fixed to ye inner bottom of ye vessel. there was placed at ye side of ye hole at ye same height where when taken 12 inches wch were divided into 36 parts; ye first from ye hole had one of those parts, ye 2d 3, ye 3d 5, ye 4th 7, ye 5th 9, and ye 6th 11: ye first division from ye top ran out in 36 seconds of two following of same: ye 4th employed 36 seconds and each of ye other yet less, although ye water made then a turning round wch might accelerate the acceleration of ye water when it went thro ye hole. ye same proportion is yet less observed when ye hole is very great in proportion of ye height as if it had its diameter equal to ye 4th or 5th part of that of ye base of ye cylinder A B C D: for ye water will run in great abundance and by consequence will much accelerate its swiftness in descending and will shoot so strongly that wch goeth out that although its weight is then less than when it was in A B it impulse will suppose that default, and there will go out more water thro ye hole K when ye upper surface shall be at A I or L M than when it was in A B. this truth will be easily known if we consider that when a pipe is all open, ye upper water descends in equal times according to ye odd numbers following 11, 9, 7, 5, 3, 1, &c and that when ye pipe is very Longe, and ye hole very small it descends according to ye numbers 7, 9, 7, 5, 3, &c and it follows necessarily that we can proportion ye heights, ye wideness and ye holes of ye pipes so as to temper ye swiftness as we please, that is to say that we may make 2 halfs pass in 2 equall times, and that ye 3d part towards the base shall be void in a time 3 times less than ye rest, and so of ye other parts: but when ye water shall be so descended as in E F, it will not any more accelerate but always diminish its swiftness: for then ye pressure shall be more than half diminished and ye acceleration necessarily cease much, and it will go always diminishing to ye end. It is experimented in a pipe of glass of 5 feet high of 10 lines Large, and two lines ye hole, divided into 5 parts that ye first will pass in ye measure of time ye second and 3 in 6, and ye 4th in 7 near, and ye rest always diminishing: whence it follows that in such a pipe there is 2 different places one towards ye top and ye other towards ye middle of ye pipe where ye water descends with ye same swiftness: hence is seen that it is impossible for ye water to descend uniformly along cylindric vessels what Large they be their Largeness their heights and ye holes or Ajutages) for it ye weight wch it hath in A I ioyned to ye impulse of its swiftness makes it go out with a certain swiftness thro K ye impulse of ye same swiftness if it persevered it, ioyned to ye weight it hath in L M, wch will be less will make it go out less swift and by consequence the upper water will descend less swift in L M than in A I, whence it follows that in ye beginning ye upper water diminisheth its swiftness it will diminish to ye End.

whence we may judge in what time a
mud will be void pressing it to run thro
a certain hole: for let A B c D be a mud
of pans placed on one end having a hole of 4
Lines in E, & ordinary height of ye mud be-
-tween 2 heads wch is 30 inches, or 2½ feet,
by 13 feet makes 32½ wherof ye vent is
5 12/17 near, and as 13 to 5 12/17 so is 14 to
6 1/7 near: therefore if ye hole E is of 3 lines,
there will go out ye mud being kept full 6 1/7
pints in a minute but being of 4 lines the
surface of ye holes are as 9 to 16: therefore
as 9 to 16 so is 6 1/7 to 10 2/7 that is to say
to almost 11, and if 11 pints give 1 minute, what
time will 280 give, we shall find about
25½ minutes keeping ye vessel always full
of water therefore but what is said above,
a double time is necessary, viz 51 to let
it run out.

It is convenient here to resolve a problem sufficiently curious
wch Torricellius hath not attempted to solve altho' he proposed it: ye problem
is to find a vessel of such a figure that being drawn off at ye bottom with a
small hole ye water may passe in descending from equall heights in equall
time. If ye conoidal figure B L is to B H, as ye sq sq of L n is to ye sq sq
of n o, and B n to B H as ye sq sq of n o to ye sq sq of H K and so on ye waters
wch descend from A b c uniformly to ye hole wch is in B: for let
B p be a mean proportionall be-
-tween B b and B H, since ye sq sq
of K H and of b c give one to ano-
-ther as ye heights B H B b ye sq sq
of H K, b c will be in a subduple
proportion of B H to B b, or as
ye heights B p (B D; but ye swift-
-ness of ye water wch goeth out
in B by ye change of ye height B
b is to that wch goeth thro' ye
change of ye height B H in a sub-
-duple proportion of B b to B H
is as B D to B P: therefore the
swiftness of ye water descending
from H is to ye swiftness of ye
water descending from b, as ye
sq of H K to ye sq: of b c: but
ye circular surface of the
water in H is to ye circular
surface of ye water in b as
ye sq: of H K to ye sq: of b c
therefore they will run and
descend as fast one as ye other.



And if ye surface A D C runs out in one second, ye surface G H K will run out
also in one second since ye quantitys are as ye swiftnesses. ye same thing will
happen to ye others surfaces in E and F &c but it is necessary that ye hole in
B be very small that it may not make any considerable accelleration
and that ye water may not go out of ye hole B sensibly, but in pro-
-portion of its weight. such a vessel may serve for a as water hour glass.

Explication in numbers

Let b B be 16 and B H & the sq of H R shall be 1 it & sq sq of b C is 16 and by consequence b C shall be 2 it H R is 1. Let B H be a mean proportional between B H & B D, such shall be by consequence 4: & swiftness by & weight H B shall be 4 it & swiftness of & weight b B is 16: but & circle on & surface H R shall be one & circle b C 4: throughout these quantitys will be as their swiftnesses and by consequence in & same time & circles or surfaces b C and H K will be emptied: and if there is need of a second of time for & surface H K to run thro its quadruple will run thro in & same time by a quadruple swiftness, is & surface b C sinck it is quadruple to & other. & same proportion will be found in all & other surfaces, wch compose all & vessels or in & solids wch have a thickness, mitigible small. we shall see in all these experiments that there is no running round in & water nor any small hollow, as in vessels wch avoid themselves.

Rule

If there be 2 pipes of equall height and unequal Largness (whatsoever their inequality is) and that & water goeth out at their bottoms thro equall holes there will no more water go out & straight pipe than thro & large in & same time keeping them full, provided that & Lesser pipe hath its diameter about 4 times as Large as & hole thro wch & water goeth out, and that & water hath no circular motion in & pipes: for & waters going out thro equall holes will elevate equal weights as is said above, it will go therefore as swift in one as in & other and by consequence there will go out as much water in & same time: If there is therefore a great vessel of 100 feet diameter and one of a foot equall height, and pierced at & bottom as at & side with equal holes of & same height from & surface of & water there will go out as much from one as from & other in & same time.

It is made a question whether if there is 2 pipes of an inch large and unequal in height for example one of 5 feet and & other of 10 and that these were filled with water, if they would give as much water one as & other because & water in all & two fulls equally swift, as two unequall cylinders of & same matter in & beginning of their fall: because & air resists both alike and they are accelerated equally likewise according to odd numbers: therefore if there goeth out 6 feet of water in a certain time from one there will go out as much from & other. but if we shorten & great pipe to 4 lines at its back, it will give more water in & first fourth of the second than it it were all open: this is & calculation.

The product of 13 by 52 is 676 whereof & root is 26, as 13 to 26 :: 14 pints to 28 therefore in a minute that hole will give 28 pints, or 56 pounds; and by an hole of 4 lines 99 pounds $\frac{1}{2}$ and in one 2 about 26 ounces and $\frac{1}{2}$ and in $\frac{1}{2}$ of a 2 $6\frac{1}{2}$ ounces; but in one tenth of a 2 the cylinder of water descends but $\frac{3}{2}$ of a foot, wch upon & largeness of an inch goeth a little more & 4 ounces therefore in $\frac{1}{2}$ of a second there goeth out of & great cylinder $2\frac{1}{2}$ ounces more water thro & hole of 4 lines, than from & small cylinder all open:

Discours V

Of the measure of running waters in an Aqueduct or in a river

To measure & running waters in & conduit of an Aqueduct or those of a river such we cannot receive into vessels we may observe the following method.

We put upon & water a bowl of wax charged with a little heavier matter, so that there may only a little of & wax pass above & water for fear of wind, and after having observed 20 or 15 feet long & Aqueduct we account with a pendulum of half seconds in what time & bowl of wax carried by & course of & water will pass that distance afterwards we multiplie & Largeness of & Aqueduct by & height of & water, and & product by & space & wax went thro & last product wch is a solid did mark all & water wch did pass in & time observed thro one part of & Aqueduct to make that operation with swiftness, it is necessary that & bed of & water hath & same steepness as the

superficies of ye water wch passeth thwo and moveth it is supposed ye water equally swift at ye bottom and top and towards ye sides.

Example

Let us suppose an aqueduct wch is two foot large, and that ye water is a foot high and that in 20 seconds ye wave went 30 foot that shall be 1½ foot in a second but because that ye water goeth slower at ye bottom than at ye top we must take but 20 foot that shall be threescore 1 foot in a second, ye product of 1 foot high by 2 foot large is 2 wch multiplyed by 20 long gives 40 cubic foot or 40 times 35 pints of water wch maketh 1400, 60 seconds will give 3 times as much viz 4200 pints and dividing 4200 by 14 wch is ye number of pints an inch of water gives in a minute, or 60 seconds ye quotient will be 300, wch shall be ye number of inches wch ye aqueduct will give.

We may calculate easily after this manner ye number of inches that ye river Seine will give: for since there passeth below Parthenage in a minute 2000000 cubic feet of water, if we multiply 35 wch is ye number of pints contained in a cubic foot by 2000000 we shall have 70000000 of pints being divided by 14 gives 5000000 wch is ye number of inches ye River Seine gives when it is in its mean height:

If we would calculate great holes as a square toise, we must consider ye height from ye surface of ye water above ye middle of ye toise Let it be for example 8 feet there will be therefore 8 feet to ye middle of ye toise the product of 8 by 13 is 104 whereat ye square root is 10 1/2 near as 13 to 10 1/2. so is 14 to 11 near: and ~~[illegible]~~ because that an inch wound is 16 times as great as a round of 3 lines an inch surmounted by 8 feet will give 16 times 11 pints, or 178 pints wch divided by 14 give 12 inches 4 for a hole of an inch diameter. A hole of 12 4 by 144 is 1810, ye foot wound will give therefore 1810 inches. ye toise wound contains 36 times ye foot wound, ye product of 36 by 1810 is 65160 as 11 to 14 so is 65160 to 82930: therefore ye toise square will give 82930 inches

Whence is known that if ye river Seine had been retained when it is a little more than in its mean height, and that it was elevated to 8 feet above a square hole of 10 feet and of 18 feet Large it would all pass thwo: two it would have to take centre of ye circle wch was 10 foot diameter 13 feet from ye surface of ye retained water, and would give an inch into a hole of 3 lines diameter, thwo an inch diameter it would give 16 inches, thwo a foot 144 times 16 inches wch make 23 04 inches and multiplying that number by 100 ye square of 10 foot, wch is ye Largeness of ye hole it would be 230400 and according ye proportion of ye circle to ye circumscribed sq: wch is as 11 to 14, we shall find near 293236 square inches and adding to it 8 feet in length, we shall have more than 5000000 inches wch is what ye river Seine gives being moderate as hath been said above; and by consequence it will pass all thwo a sq hole wch is 18 foot large and 10 high.

The water runs thwo an aqueduct or thwo a channel of a river according to an uniform small steepness it will acquire in a moderate space a swiftness wch it will not augment: but ye rubbing of ye sides and of the bottom of ye channel and ye impairing of ye parts of ye water worn above below and ye assistance of ye air to ye small waves wch are in its surface make it lose one part of its swiftness, and by consequence it can accelerate its motion but to a certain swiftness wch it will acquire in a little time: whence it follows that if a river hath run thwo a sufficiently long space in a certain declivity and that it runs afterwards thwo a declivity ~~and that it runs afterwards~~ less steep, that is to say thwo a plain less inclined it will diminish its swiftness: for since it had acquired in ye first declivity all ye swiftness it could have there, wch it could not have acquired in a lesser it follows that it will diminish its swiftness a little in that declivity wch is less, till it is reduced to ye swiftness it could acquire there

Part The Fourth
of the Height of Spouts

Discours I
of the height of perpendicular Spouts.

It is seen above that Spouts ought to mount to ye height of ye reservatorys but that ye rubbing at ye sides of ye holes and ye resistance that ye air makes causes that in Spouts highly elevated ye height of ye Spout doth not arrive to that of ye reservatory.

To explain well ye rules wch we ought to observe in calculating ye heights of ye Spouts according to ye heights of ye reservatorys, we must consider ye following rules

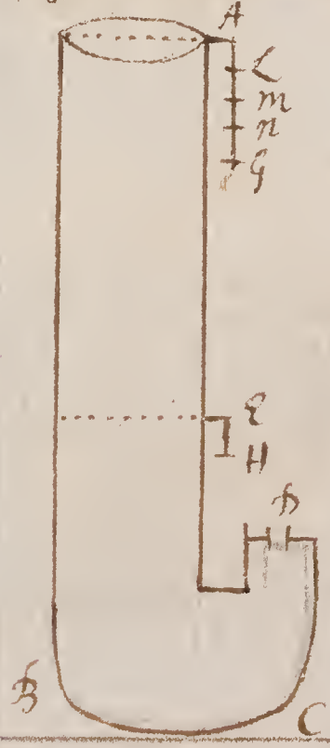
Rule the First.

ye hole of ye pipes wch furnish ye water are sufficiently large ye larger ye hole is further it pusheth its Spout an experiment is easily made if we have a vessel of water and pierce at ye side towards ye lower end with 2 or 3 different holes of ye same horizontal height as of 1, 2, 4, 6, 10, 12 lines &c for we shall always see ye largest hole push ye water further provided ye holes be at ye same distance from ye surface of ye water: ye same thing will happen in 2 pipes of 3 or 4 inches Length provided that ye hole exceeds not a diameter.

The cause of this effect is easily to be explained to boys of wood of different bignesses: for since they go out by another in triple proportion of their diameters, their weights will be also in that proportion: as also their force to surmount ye resistance of ye air: and by consequence if we cast with ye same swiftness a bowl of 2 Lines diameter and another of 4 that last will go further. we see an experiment when we put into ye same gun Lead in powder shot and bullets; for although they go out with ye same swiftness ye shot goeth much further than ye powdered Lead, and ye bullets get much further than ye shot. and so ye same reason will go further than a small ball of ye same metal pushed with ye same force. it is true that if ye reservatory is but 2 or 3 feet a spout of 8 Lines will not be sensibly different from a spout of 10 or 12 Lines and one of 4 Lines will go sensibly as far as one of 6 but ye difference will be very considerable to spouts of 30, 50 and 60 foot high and beyond.

Rule II

The spouts diminish of ye height of ye reservatory in a double proportion of ye height where they are elevated:



Let A B C be a reservatory or pipe spouting thro ye hole b, and let ye height of ye water in pipe successively be A and e: I say that if ye Line b H is ye defaut of a small spout to E and g A ye defaut of a great spout to A H g shall be to E H in a double proportion of b H to b g.

For let us suppose that ye weight of ye air is to ye weight of ye water as 1 to 600 or else the Law of calculation as 1 to 60 and that one Solid drop or parcel of air is mounted by y going out thro ye hole by ye first drop of water and that it afterwards is moving freely as in a vacuum. It is evident by what hath been demonstrated in ye rules of ye motions of bodys wch shoc one the other that ye drop of water will Loose $\frac{1}{61}$ of its swiftness if its swiftness is expressed by 61. therefore Let b E be 61 and b H 60, and that ye drop is retarded $\frac{1}{61}$ viz E H. furthermore Let ye height be b H, ye swiftness of ye drop shall be to ye first swiftness in a subduple proportion of b E to b H and that drop by mounting a small parcell of air

will loose yet a part proportionall to # ℓ according to ℓ proportion of bℓ to bℓ, let #ℓ be that diminution bℓ shall be to b# as b# to bL: but as we supposed one pascell of air for ℓ space bℓ there will be as many pascells of air for ℓ space b A in proportion as bA or bℓ is greater then bℓ or b# and each pascell diminisheth ℓ rigidity ℓ height of ℓ drop of water in ℓ same proportion, that shall be a second proportion equall to ℓ first, and by consequence A L being to A ℓ as bℓ to b# or #ℓ to AL; Aℓ shall be ℓ defect of ℓ height of ℓ elevation of ℓ drop of water but because there is many pascells of air betwen b and ℓ each of wch retards ℓ motion of ℓ drop in ℓ same proportion ℓ motion of ℓ drop in ℓ space bℓ shall be much more retarded then by ℓ incounter of one sole pascell as is supposed. but we may comprise all ℓ sphere of air as one sole pascell, and ℓ space of air bA is in ℓ same proportion as bA to bℓ and by consequence we might add a second proportion equal to ℓ first: whence it follows that it AL is to Aℓ in a double proportion of bℓ to bA; ℓ A shall be ℓ defect of ℓ front below ℓ height of ℓ water of ℓ reservatory bA if ℓ # is that of ℓ height bℓ wch it ought to be:

Example

Let bA be ℓ quadruple of bℓ ℓ swiftness of ℓ front of water pushed by bA shall be double to that of ℓ front of water pushed by bℓ. if we take there as above ℓ height bℓ for 60 ℓ height b# shall be 60 and as ℓ swiftness of ℓ great front is double and that it ought to be elevated to a quadruple height will loose by ℓ incounter with as much air in bℓ 4 times as much of ℓ height as #ℓ that is that in stead of ℓ fronts being elevated to bAℓ 44 it will be elevated but to bℓ 240, but ℓ space ℓA being divided into 3 equal each shall be equall to bℓ, and if ℓ first length A L, ℓ second shall loose as much in ℓ same proportion as ℓ different parts of bℓ loose to ℓ first front: for in each part of ℓ front with out ℓ swiftness of ℓ great one is always double to that of ℓ small, for it hath always a quadruple space to pass thro: it will loose being ℓ first part ℓ other equall ones Lm mr ng and AL being supposed A# shall be 16; and by consequence ℓ default Aℓ shall be to the default ℓ # in a double proportion of bℓ to bA and if ℓ # is 1 inch ℓ A shall be 16.

The rubing changeth a little these meshures and ℓ complication of ℓ spaces of ℓ air wch weights: for in ℓ great fronts it will be very convenient that ℓ space of ℓ air pascell may be in proportion as ℓ height of ℓ reservatory wch might a little to diminish ℓ default and it is ℓ height of ℓ fronts must be considered, and so if # b is 60, bℓ shall be 240, ℓ small reservatory being at 61 foot and ℓ great one at 256 foot:

upon that supposition it will be easy to calculate ℓ heights of ℓ fronts to all heights of ℓ reservatorys one being known as that of a new vatory as 5 foot wch is found by many experiments to want an inch. if we suppose therefore that a front of 5 foot wherof ℓ water ascendeth if it not straight and runs easily in ℓ pipes ought to have ℓ upper surface of ℓ water of its reservatory at 5 foot 1 inch, a front of 10 foot shall have its reservatory at 10 foot 4 inches; that of 15 foot at 15 foot 9 inches: that of 20 at 20 18 inches and so in order according to ℓ squares. we must not calculate by diminishing ℓ heights of ℓ reservatorys: for if we take a reservatory of 100 foot it will diminish 400 inches that is 33 foot 1/3 one of 200 foot should have its diminution about 133 foot, and one of 400 foot ℓ quadruple of 133 foot viz 532 and by consequence will not spout at all wch is impossible: for ℓ fronts to that height ought allways to increase: but we must take for a front of 200 foot ℓ reservatory of 333 foot and for a front of 400 feet 932 foot

For all the different heights we may make use of ℓ following Table.

Height of the Spout	Height of the Reservatory	
5 foot	5 foot	1 inch
10	10	4
15	15	9
20	20	16
25	25	25
30	30	36 or 33 foot
35	35	49
40	40	64
45	45	81
50	50	100
55	55	121
60	60	144 or 72 foot
65	65	169
70	70	196
75	75	225
80	80	256
85	85	289
90	90	324 or 117 foot
95	95	361
100	100	400

So that a Spout of 30 foot will have a Reservatory of 33 foot; that of 60 72 foot, that of 90 117 foot that of 100 133 foot $\frac{2}{3}$, that of 120 168 foot: & Table is made no longer because it is not ordinary to make a Reservatory of 168 foot, and a Spout of 120 foot would dissipate its force by its violence into small unpercevable drops, as those of mists & pipes may be broke, and when the pipes are straight on that y^e Cock we have to let the water out at is much straighter than the weight of the pipe, & small Spouts will twice more than according to this measure, and then there goeth out less water than in proportion to the height of the Reservatorys.

we shall then calculate the expence of the water according to the heights of the Reservatorys to wch the height of the Spouts agree as if a Reservatory of 30 foot gave a Spout but of 20 foot by reason of the hinderance it could give on other things, then we must calculate the expence of the water of the Reservatory only at 21 foot 4 inches, with a lawgauge of conduit sufficient.

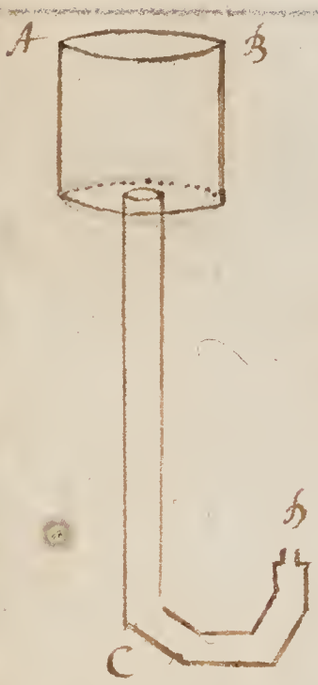
To know the diminution of the heights more than according to this rule when the holes are small I have made the following experiments.

The Spout thro one Line at a pipe of 4½ foot wanted near 6 inches

At one of 27 it wanted about 8 foot, wch shews that the straight Spouts Spout not to attain their height:

To know without calculation the height of the Spouts, we must have a ball of lead and of wood each of the Lines diameter and cast them with the same force on high: if that of the lead is elevated to 27 foot and that of the wood to 29 foot ½ that shall be a mark that a Reservatory of 27 foot shall make its Spout but 29 ½ foot thro a hole of the Lines; for altho the ball of wood be lighter than the water, the lead is also a little retarded by the air; and if we cast the same ball with a small ball of wood of one Line, and that the lead goeth 14 foot and the little ball 11, that shall be a mark that a Spout thro a Line a Reservatory of 14 foot will mount but to 11 foot:

To confirm this rule I have made these other experiments following.



we took a pipe of 3 inches bore at ye top of wch was soddered a vessel of a foot diameter, ye figure of ye pipe was as in ye figure A B c b, ye lower part was crooked; we put ye reservatory A B at different heights to make different experiments.

The water of ye reservatory being at 24 foot 5 inches higher than ye hole b, ye sprout mounted to 22 foot 10 inches; ye hole of ye spring out was 6 lines, ye square of $22\frac{5}{6}$ is $521\frac{13}{36}$ therefore we say that as 25 ye square of 5 is to $25\frac{13}{36}$ so is 1 inch ye height of ye reservatory above ye foot, to a little less than 2 inches wch ought to be added to 22 feet 10 inches to have ye height of ye reservatory according to ye preceding table. wch makes 24 foot 7 inches near such a guess well enough with ye experiment.

The sprout of 4 lines at ye same height of ye reservatory mounted but to 22 foot $8\frac{1}{2}$ inches and was lower but inch or $1\frac{1}{2}$ inch that that whose passage was 6 lines: but that of 3 lines was lower than that of 6 lines near 8 inches and was but 22 foot 2 inches.

A reservatory of 12 foot $\frac{1}{3}$ made ye sprout at 6 lines reach to 12 feet that is a little more than according to ye rule.

Another reservatory of 5 foot $\frac{1}{3}$ height in a very large conduit ye passages being 3 lines 4 lines and 6 lines call ye sprouts to mean 12 lines below ye surface of ye water of ye reservatory, and that of 3 lines differed but about one line $\frac{1}{2}$ from that of 6 lines. By ye calculation ye square of $5\frac{1}{3}$ is 30 $\frac{1}{4}$ and by ye rule $\frac{1}{2}$ 25 feet is to one inch as 30 $\frac{1}{4}$ to 1 $\frac{1}{4}$ a little more wch would give ye height of ye reservatory only one line less than by ye experiment, wch is not possible to be observed.

The small sprouts in small heights loose very little by ye shoc of ye air and are little less height than those of 6 lines, provided ye pipes are large enough: ye curvature of ye length doth not augment ye height of ye sprout, nor ye greatness ye running, or ye expence of ye water when once it fills ye pipes full. For ye sprout such the water can sustain that ought to go out is always of equal power, and supports weights according to ye greatness of ye hole of its passage.

The reservatory being at 26 feet one inch ye hole of 6 lines, it cast to 24 feet $\frac{1}{2}$ being $588\frac{1}{16}$ as 25 is to $588\frac{1}{16}$ so is 1 inch to 23 inches $\frac{1}{2}$ near, wch ought to be added to 24 feet 4 inches to make ye height of ye reservatory, wch is the surface 26 feet 1 inch, as ye experiment shews.

The reservatory being at ye same height with a passage of 10 lines sprouted to 23 feet 9 inches and thro a hole of 3 lines it sprouted to 22 foot. in ye first of these experiments ye default of ye height proceeds from hence that ye passage was too large for a conduit of 3 inches and that ye water going very swift had much rubbing; and in ye second ye smallness of ye sprout wch leaving much air to pass thro was considerably retarded and its height diminished, as is explained in ye first and second consideration.

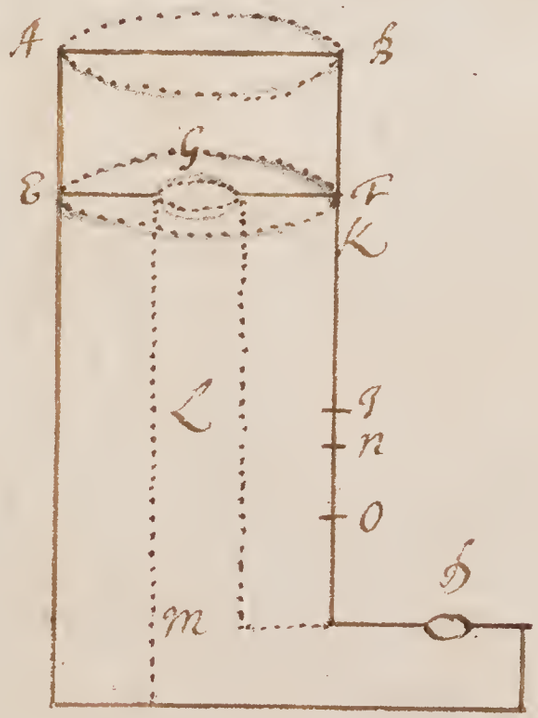
The water of ye reservatory being at 35 foot height less by half an inch thro a passage of 6 lines, ye sprout was cast to 31 feet 8 or 9 inches; and by ye rule ye square of 31 feet $\frac{1}{2}$ being 1002 near and 25 is to 1002 as 1 to 40 inches near, that is 3 feet 4 inches wch being added to 31 feet 8 inches make 35 feet; so that experiment is conformable to ye rule.

Thro ye same reservatory thro a hole of 3 lines sprouted to 28 feet; one of 4 lines to 30 feet and one of 5 lines to 27 feet only for the same reasons wch have been said viz that in ye last experiment ye conduit of ye pipe was not large enough for ye greatness of ye sprout, and for ye expence of ye water, and in ye two former, that ye height being great ye air did too much resist ye small sprout of 3 and 4 lines

I made also experiments with a reservatory of 5 feet high, and ye proofs followed ye same rules, ye passage of 6 or 4 lines made ye highest sprouts.

when there is a great reservatory as of a foot on ye top of a pipe of 50 or 60 foot high and of three inches Lardge: it happens that making a spout of 9 or 10 lines it doth not mount so high as it ought in proportion to the height of ye reservatory; for ye water of ye reservatory cannot come to spirt from ye sides wch are taken off from ye hole to enter into ye pipe, and its owing=ing makes a kind of whirlpool because of ye too great distance of ye water wch is made thro ye passage joyned to ye running in ye pipe as hath been explained formerly. whereof there follows an effect sufficiently surprizing wch is that when ye spout a first goeth to a height as of 45 feet it diminisheth and goeth but to 44 feet and afterwards it remounts to 46 or 47, wch arrives as soon as ye air can enter thro ye hole of ye vessel; for then begines ye accelleration of ye water wch goeth swiftly & height of ye spout is made ac=cording to ye height of ye water from ye bottom of ye vessel, and it not hindered by ye superiour water this reason is confirmed by ye following experiment.

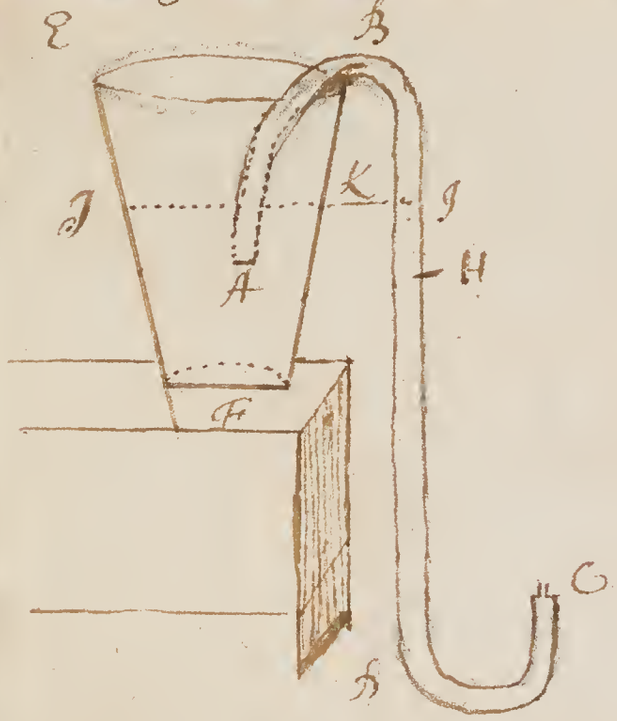
There was made a reservatory of 6 foot high as A B C D and at a foot below ye highest place we fastned a plate within wch is pierced with an hole of 8 Lines diameter in G. we poured water till it began to run thro ye hole B and stopped that hole B using up ye reser=vatory. to do it sooner we must make a small hole below F as in K that ye water entering into ye reservatory through the hole G ye air may go out easier, and stop it afterwards when ye pipe shall be full to E F to fill up ye reser=vatory to A B. this reser=vatory being full, we permitted ye hole B to run and ye spout mounted at ye beginning to I and diminished by Little and Little till it was below ye plate: for then ye water was elevated unto K.



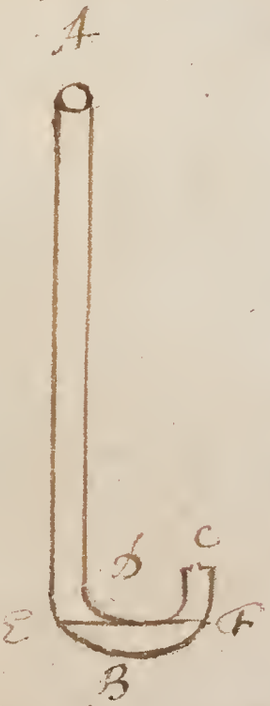
The effect is ye same as that of ye great running out of ye water when we put a small pipe at ye hole of a large reservatory.

for then ye water runs thro ye cylinder of water G L m b in like manner as it was a pipe ye rest of ye water having no considerable motion because of ye plate. but when ye water is below I and that ye air begins to pass there, all ye water E F m is free to act upon b, and it ought to spout very neare to F. ye effect shall be yet more strange if ye hole b is 6 or 7 lines and ye hole G 3 or 4; for ye spout will go at first no higher than O n and will decrease to O, and ye water being below G it will remount almost to F.

After ye same manner if there is a syphon as A B b C wch makes ye water run out of a vessell E F whose surface is J K, through B A b c it will spout through a small hole into it, and if ye syphon was less long, it spout would be elevated less high from its hole in C: but when there shall be no more water in ye vessell below A ye pipe will be void from it to B and when ye height of ye water shall be in B it will spout to J if ye syphon is 5 or 6 times longer and ye hole c small as of 2 lines because there ye weight is made by ye height B C and ye height and ye weight keeth always till ye water of ye vessell be below A.



It seems to be ye weight of ye water wch give ye elevation to ye spout to reduce to an equilibrium, and that if we should press ye water wch is near ye hole with a weight equal to that of ye water of ye pipe it would spout as high. See an experiment I made to prove it.

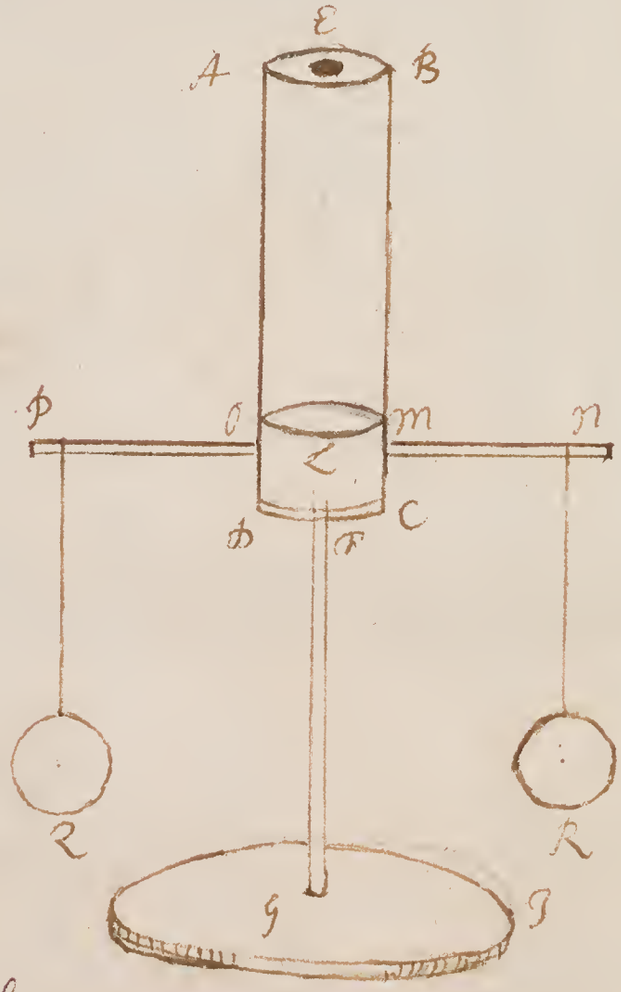


A B is a pipe of glass of an inch and ½ long its height b A is a foot & hole c passage (is 2 lines ½) we poured mercury thro A till ye bottom ye C way filled we afterwards put water gently into ye space c E afterwards we stopped ye hole c with ones fingers and filled ye pipe with mercury into A. when we took away ye fingers from ye hole C ye water E C of was elevated to near 12 or 13 feet, ye cause of this great elevation is ye specific weight of ye mercury wch is to that of water as 14 to 1. by consequence 1 foot of mercury in b A will weigh as much as 14 feet of water, which should be in a greater pipe and should produce ye same effect in spouting water thro C. and because a reservatory of 14 feet spouts ye water to about 13 foot, a foot of mercury ought to produce ye same effect. It is no matter whither ye pipe be larger or small, provided it be proportioned to ye hole C.

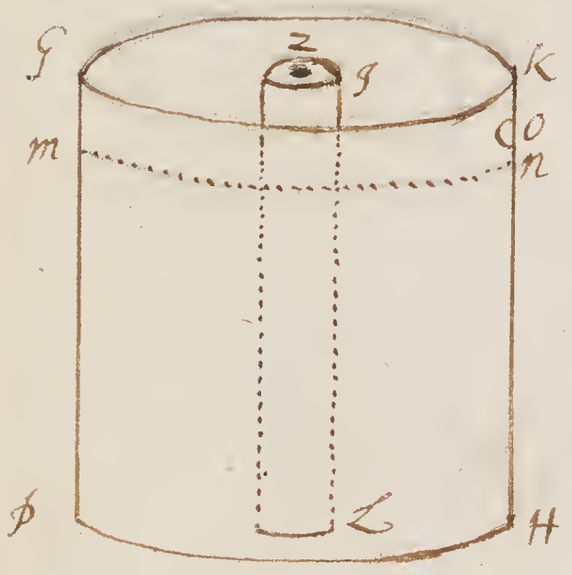
=stead of ye weight of water or quick silver. For example.

The like effects will follow ye weights placed upon a syringe in-

Let A B c D be a syringe of 3 inches Large having at its



going out a hole of 4 inches in ye sucker is F g, wch hath a plate # A be=
=longs its handle to wch it is fastned that ye syringe may be kept straight, ye
sucker being within, it had wings from ye top of ye sucker L to E, m n, O p, are
two sticks tied to ye body of ye syringe on wch are hanged by two cords on
each two equall weights Q and R: I say if these two weights weigh 20
pound, ye spout will shoot thro E, as high, as if a reservatory, wch had com=
=munication with ye hole E, and whose pipe wch contained ye water was equal
in thickness to ye body of ye syringe A B c D, was high enough to contain
20 pound of water. now ye pipe being 3 inches Large it will have nine inches
surface, each of which weighs 6 ounces: there is therefore 54 ounces or 3
pound 6 ounces upon each foot in height and if ye reservatory was 6 feet
it would be 20 pound 10 ounces: therefore ye spout should go about 6 feet
suffering ye rubbing of ye sucker to be but ye value of 10 ounces: so if the
two weights were of 40 pound, they would shoot ye water to near 12 feet,
and if they were of 100 pound it would shoot as if ye pipe was 30 foot high.

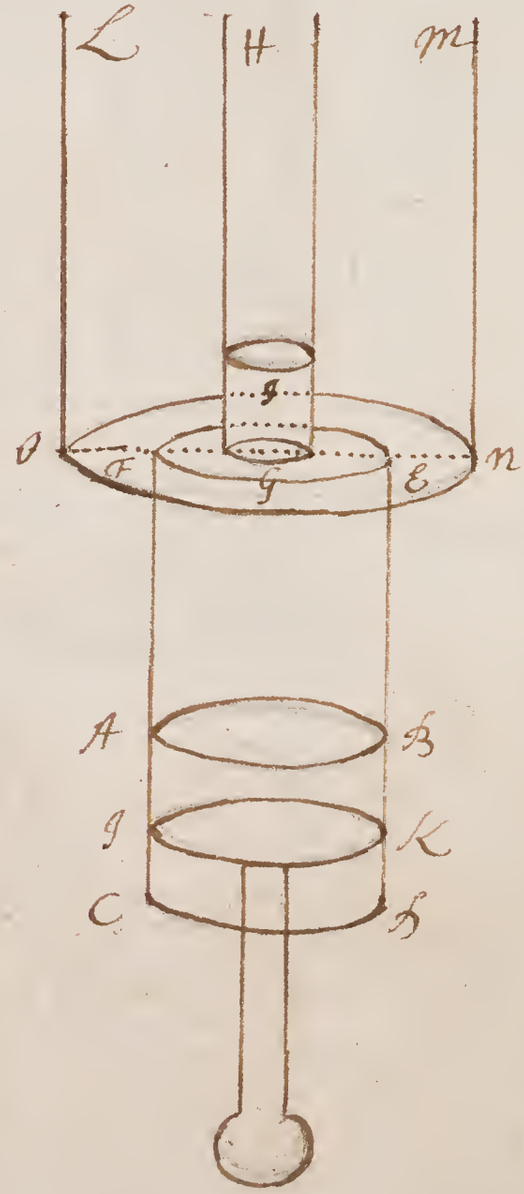


But if there is made a vessel of copper f k p h whose upper plate may be very thick to sustain a great effort: and there is put in it a hollow cylinder l l, the vessel being full of water to m n, and there is a hole o through wch to syringe f air by means of a wch shall be having stopped hole z when f air shall be 4 times condensed its effort shall be equal to 4 times 32 feet of water: and if the vessel was of a foot diameter each foot of water in height would weigh 55 pounds that would be therefore 128 times 55 pounds or 7040 pounds; there would therefore be need of 7040 pounds to condense f air 4 times: but if the hole o was $\frac{1}{10}$ of an inch, and the base h p one foot, the proportion would be as 1 to 2304, and the force of 4 pounds would make the air enter to 4 times that number: that is to say to carry the weight of 9216 pounds; it would carry therefore as great a weight as that of 128 feet of water and by consequence when the hole z was opened the spout would go to near 100 feet.

But if the vessel was longer the air wch should be between m n and c k, would not be more difficultly condensed by the hole o, as is proved in the treatise of percussion, and would not hinder its producing the same effort to spout to 128 foot high as a pipe of all-the length full of water.

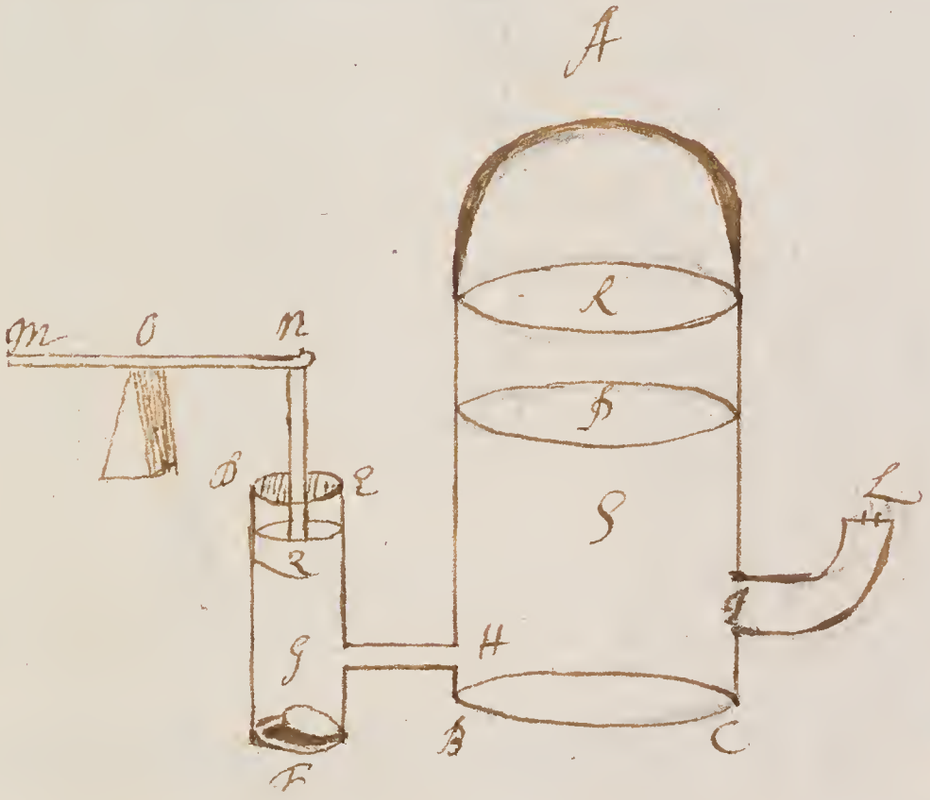
I made also the following experiment. I took 2 unequall syringues, one of $2\frac{1}{2}$ inches diameter, and the other $3\frac{1}{4}$; in that of $2\frac{1}{2}$ inches the 5 pound weight made the sticker descend. and having fixed the syringues and pushing the sticker with a force near equal to 12 pounds I elevated the water by the 2 a hole of 8 lines, to near 4 feet: now a foot height of the pipe of the syringue is near as much in value as 32 ounces or 2 pounds, and 4 foot are in value about 8 pounds. If therefore the effort was of 13 pounds, taking away 5 pounds for the rubbing of the sticker there will remain 8 pounds for the weight equivalent to the water of a reservatory of a little more than 4 foot height. and of $2\frac{1}{2}$ inches diameter: the other syringue gave the same in proportion.

If we push the sucker A B K I into its body of G



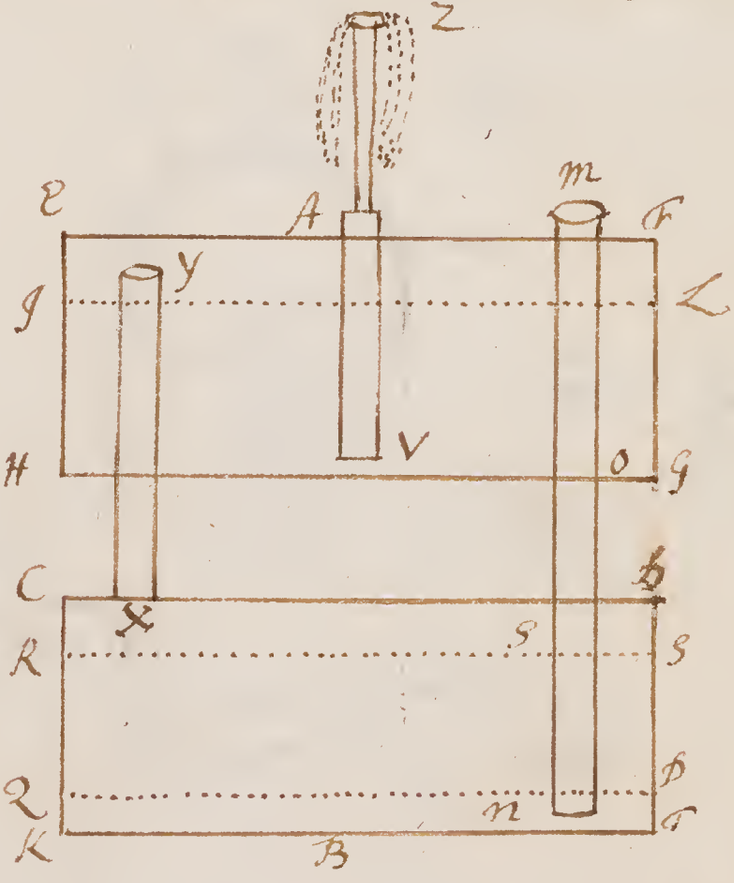
pump C b F E wch is straighter higher, as is seen in ye figure I H, ye
great rubbing of ye water along ye straight pipe G H considerably stops ye force
of ye impulse to make ye water pass contained in A B E F, and it would pass
better there if their conduit were but to I, and much better if it was Longer than
ye body of ye pump where ye sucker plays as L m n o, wch might be, considering
which ye water is elevated thrô pumps to great heights.

ye following method. We may also push a front very high according to



foot height and of 8 inches large, placed and firmly fastned to a plane of wood or iron have at ye side a syringue or body of a pump b e F with his sucker n e and a below, as is ordinarily in pumps and that ye sucker descending with ye force of a man or two makes by its compression ye water to enter into ye vessel thro ye pipe e H furnished with a valve m H, put at ye side of ye hollow cylinder or vessel another pipe I L bending upwards where there is a passage of 12 lines at its extremity L; it we more over fit to two sides of ye vessel 2 other pumps like to that above, we may make a great quantity of water enter. ye suckers may be fastened to ye ends of a Lever as n to have ye more force being joyned to a support m O: when we shall play ye suckers by ye means of ye Levers, ye water will enter into ye vessel A B C and will past at ye beginning with a moderate force into ye pipe I L, but in continuance we shall push so much water that it cannot all go out through ye passage L; then it will be elevated as into P and will condense ye air inclosed in ye top of ye vessel; and if we push ye water with greater force it will mount higher; as in R condensing ye air more and more; and when it shall be 8 times more than ordinary condensed, it will push ye R S H I to make it go out thro I L, as if there was 7 times 32 foot of water above H I, that is 224 foot, wch would make a front of water thro ye hole L of more than 120 foot high. but it is necessary that ye 2 pumps be able to furnish water enough; for ye passage L of 12 lines will spend more than 64 inches.

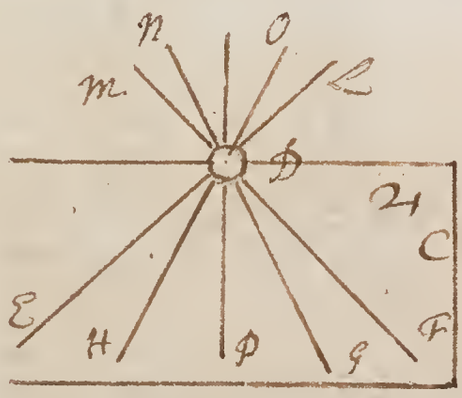
The aiz condensing it selfe according to ye weights it is charged with, if we make an Engine A B composed of a coffer E F g H full of water to ye Line L a little below E F, and a pipe m n, wch must be well soddered in m and in o



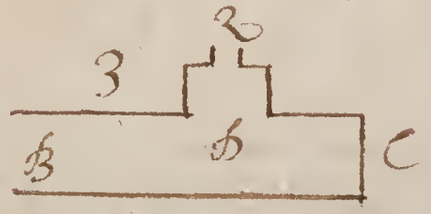
with ye two plates E F g H wch make ye upper and lower side of ye coffer to ye end yt aiz may not enter ye coffer E G will serve for a reservatory. there must also be another coffer equall to ye first as c B r k full of aiz to wch ye pipe m n must be well soddered. when water is poured thrô m it will descend through n to K r and being mounted to p R, ye aiz contained in ye space R p c b and in ye pipe x y will be condensed by little and little till there is made an equilibrium between ye weight of ye water in m n, and ye spring of ye inclosed aiz. for example if ye water is elevated to R s, ye aiz contained in ye space c b s R in ye pipe x y and in ye space E I F L, shall be condensed by ye weight of ye water m s, and will presse ye water I H I L; then if we open ye passage 4 whose pipe descends to y nigh to 4 ye water will mount ye height 4 Z equall almost to ye height m s; because that ye aiz pressed by ye height of ye water m s, makes almost ye same effort upon ye water I G as if ye pipe m s full of water was above ye water I L, and ye water which falls from ye mount ~~will fall~~ passing thrô m, will return into ye mighten coffer, and by that means ye mount will cast till all ye water [illegible] from ye extremity V of ye pipe 4 V to ye extremity 4 of ye pipe x y is spouted out. this Engine carryes ye name of Heron; he describes it in his Treatise de spiritualibus, according to ye 1st Command in.

we may spout that water much higher by augmenting ye height of the pipe m n.

The beauty of spouts in their uniformity and transparantly in their going out of ye passage without scattering as well as in their height. we have sought many ways to make ye passages, whereof there is some we put to before & left for many reasons. & would have those which are made cylindrical: for they give much stop & straight at ye spout, & conical stop it less: but ye best way is to pierce ye Horizontal plate which stops ye end of ye pipe of ye conduit with a smooth and polished hole taking care ye plate be perfectly plain polished and uniform. Here is some experiments wch I made. having a pipe of tin of 15 foot height A B C and having pierced it in b with a hole of 3 lines, ye spout was perfectly gracefull and went to 14 foot: but ye pipe having been made higher to 27 foot and having a hole in it of 6 lines ye spout went but to 12 foot being much scattered and separating it self into many drops, wch proceeded from thence that ye water wch maintained ye spout was with force pushed a crosse as it seem

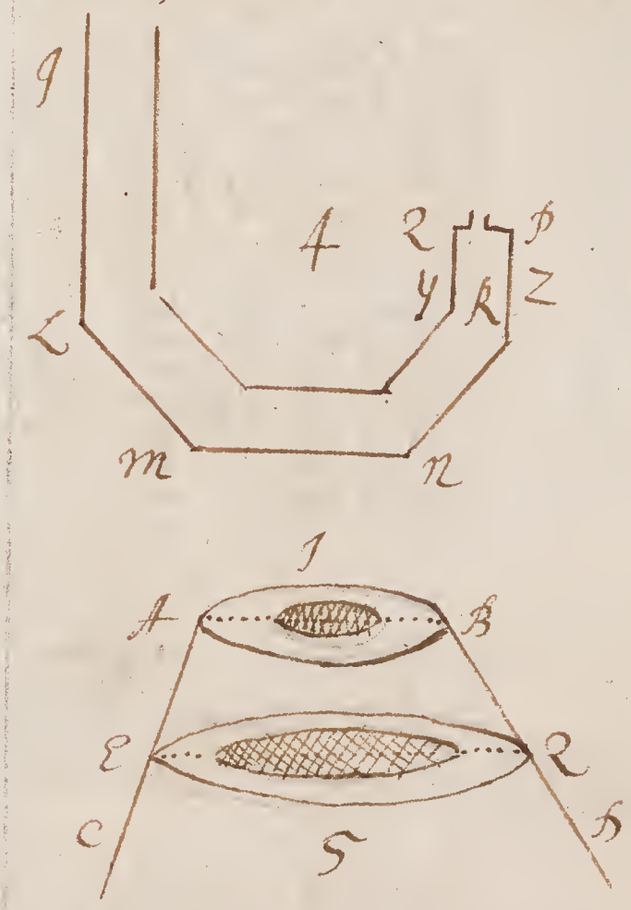


In ye second figure which represents a portion of the pipe B c. For ye water f b and f b wch cometh from ye sides hath a great swift motion, wch carrys it to b l and b m; and g b is carried to b n and h b to b o, wch scatters ye spout, because the little water which comes directly from p in b is not sufficient to sustain it.



To avoid this fault I put in b a passage of an inch long and an inch large as is seen in ye 3d figure where B b represents ye part B b c of ye first figure; we pierced it with a hole of 6 lines the small upright pipe b 2 m 2 then ye spout was very fine, and was elevated 3 or 4 foot higher.

afterwards & end of & conduit like & crooked figure l m n o p in & 4th figure and in & plate 2 p. I put a passage like to that of & figure marked S, it was a little conical but it had an inner plate represented by 2 2, of an inch or better and & upper plate A B was pierced in & middle with a hole of 6 lines wch was made to & end that there might be no rubbing but at & side of & plate 2 2 within wch there could be but very little in & A and B 2: but it succeeded very ill: for & spout went less high and scattered more than if it did thro' a simple conical passage which might come from a different motion of & water wch having passed through 2 2 did strike rectangularly & plate A B at & side of its hole and being reflected might hinder & rest of & water from going out straight. Lastly I put a very polished plate in p 2 in & 4th figure pierced with a hole of 6 lines round and polished. then & spout was very fine and was elevated to 32 foot the reservatory being at 35 foot & inches, whereas & others spouts were elevated but to 27 or 28 foot which happens because & water takes & direction of its motion from R and that it comes but very little laterally from & sides, y and 2 wch nevertheless conduce to & direction of & spout & plate being very smooth and all be equall on both sides and stopping & spout thus that hole was elevated equally & latter all motion on both: now to 32 feet without being reservated except in falling and was stopped very little at & top when it went to 32 feet, and much less than by & others passages. I have seen a plate pierced with a hole of 4 lines and of 6 or 7 small ones round about, wch made a kind of thread whole spouts were very fine and transparent, and that of & middle was elevated to 18 foot.



Whereof & reason is that the spouts are necessarily enlarged as they are elevated it is & same water wch by its viscosity is kept united & continu without being separated, it is necessary that it passes more space in & space where it goeth less swift according to & proportion of & swiftness to & swiftness.

The spouts are necessarily enlarged as they are elevated

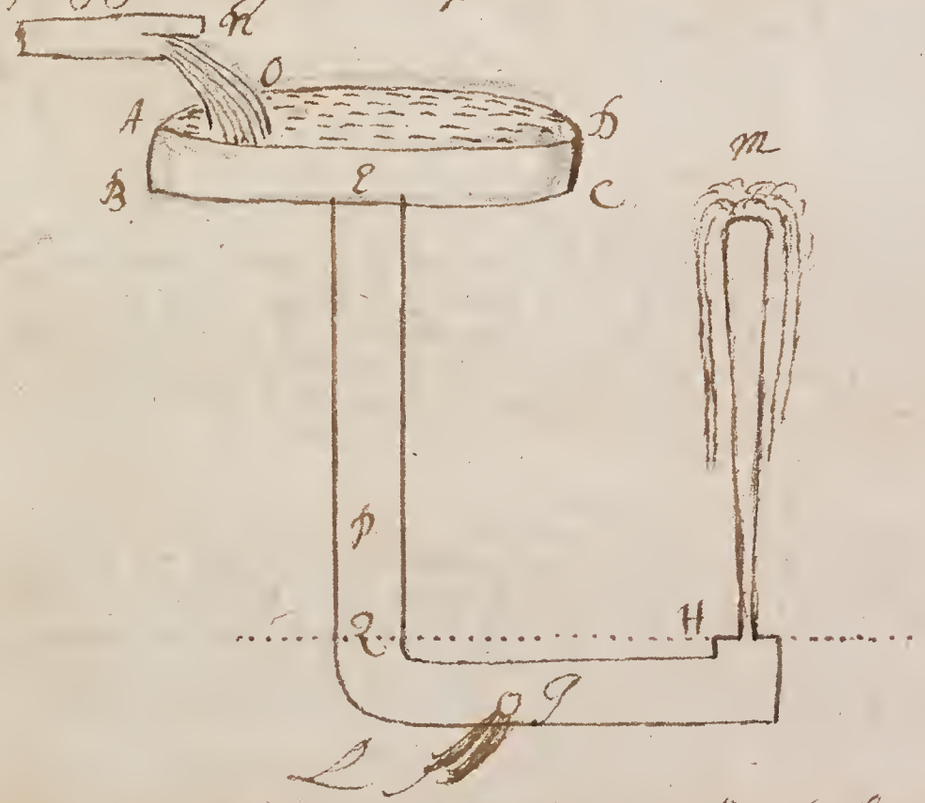
For & same reason & water wch runs thro' a hole of 6 lines when it is in & reservatory but at & height of 3 or 4 inches goeth always scattering till it is reduced into drops, when & stream of water is become very small: now there ought to be but a certain quantity of water in all & places wch it passes through in falling, which in equall times one to another at a remote or odd numbers; whence we see that & stream of water may come at & last times I have a hair, but before it comes to that point it is separated and divided into drops wch always accelerate their motion till they have acquired their greatest swiftness.

We must not regulate & dryness of & water by & height of & spouts but by & swiftness of its going out thro' & passage: now my passages

of one or two lines ye spouts do not go so high at ye same height of ye reservatory as those of 5 or 6 lines, and yet they give water sensibly in proportion to their holes. To know ye causes of these different effects we must consider that ye small globes are in proportion to ye great in a triple proportion of their diameters, but they are retarded in their motion by ye air according to ye squares of their great circles, and they force this resistance of ye air according to ye difference of their weights as is explained above. whence it happens that if we have a mas- =ket charged with bullets and small shot, ye bullets will go further than ye small shot, altho they go out of ye musket with ye same swiftness as we have explain= =ed, ye same thing extends to ye small and great passages, which have ye same height of ye reservatory, for although at ye going out of ye passages they go neer as swift one as ye other, when they past much air, ye small spouts are retarded from their going out to their greatest height more in proportion than ye gross spouts. and by consequence ye gross go higher than ye small, but they give not more water in proportion, or but little more since it ought to be effected by ye swiftness with ye spouts have at their first going out of ye passage, wch is neer equall in both small and great passages.

When there is a spout maintained by a sufficient quantity of water, and we pierce a pipe of ye conduit with a hole equall to that of ye passage thro wch ye water goeth out, we shall find ye diminution of ye first spout in ye manner.

Let A B C b be a reservatory of 13 feet high above ye passage H of a hole of 6 lines, ye spout ought to be about 12½ feet if ye conduit is 3 inches large. there is made a hole in I of 6 lines whence goeth out ye water of ye spout H m. expends 4 inches of water by ye rules wch have been given; and because there ought to go out neer as much thro ye hole I of ye conduit is too small to give ye same height to two spouts equall to H m; therefore as soon



as we permitt ye water I L to run, ye spout H m will diminish a little and because ye two holes H and I give neer 8 inches, and that ye water n O wch transmitteth ye water of ye reservatory is but 4 inches by ye supposition, ye reservatory will provide by little and little if it is very spatious and very swift if it contains but half a muid or 100 pints. It is therefore necessary that ye water descend in ye pipe till ye spout H m gives but 2 inches: for then ye hole I giving

calld 2 inches: all ye water n o shall be employed. now if foot is to ils shall 6 1/2 as 1/2 to 1/2, therefore ye height of ye water bring p 2 of 3 foot 1/2 above H the spout can be but 3 foot 2 inches and some lines according to ye rules above: and by consequence we shall see ye spout H m decrease till it is but 3 feet 2 inches and some lines, and ye water o will keep ye height of ye water to ye height 2 p:

But if we stop ye hole 1, ye spout thro H will begin to encrease till it goeth to H m and at ye same time ye water of ye conduit will be elevated above P till it is in ye reservatory A H at its first height: it will be regulated after ye same manner in other like cases.

If ye heights of ye reservatory were extreamly great, ye spouts will be dissipated by ye incounter and violent shoc of ye air and instead of going higher than ye spouts of some reservatory less high, they would go much less high.

I have made ye following experiment.

We put into a small pipe of an inch large and of 8 inches long, and strongly in ye notch of ye string of ye cross bow, and having bent it it was elevated perpendicularly; and ye small pipe filled with water; ye water being pushed by ye force of ye cross bow went out and in coming ye air with violence was very much scattered: those wch went at ye side, could not be ye spout meant, but they saw many small drops fall near 20 foot round him who held ye cross bow which who did assure us he saw ye water mount to about 30 feet: now that swiftness would belong to a reservatory of more than 600 foot, and ye spout ought to be 300 foot according to ye rules.

An other Experiment.

I charged many times a pistol of 4 inches heigh with water instead of balls and shooting that water 20 foot against a door elevating the pistol according to an angle of 45 degrees near to hinges ye water touching, there went not one drop thither. I shot ye second time 10 foot and it halfened ye same; and when he wch shot had advanced and lifted ye end on heigh he perceived some small drops to fall; lastly we shot 4 foot against a trapper put on ye top of a door then ye paper was all wet, and we found that ye water was scattered to 2 foot diameter and having shot another time 8 foot distance ye paper was not wet. If we calculate this water as a cylinder of 5 lines large and 4 inches heigh and divide ye product by a surface of 2 foot large we shall find that ye thickness shall be but 1/20 of a line: for ye solid of ye square of 5 by 48 is 1200, and ye solid of ye square of 288 lines by 1/20 is a little less than 1200 cubic lines and ye circle cylinder is of 943 cubic lines, and that of 2 foot diameter for its base is of 1131: it happens therefore that ye water being reduced yet to a little less thickness as when we shoot 10 foot, it is seperated into small drops one where of some are elevated into vapours, and ye others fall down: but they are imperceptible.

The same effect is seen when a bubble of soap is broaken: ye particles of ye water wch are very small are elevated in visible vapours and ye right falls. a stream of water thro a hole of half a line below 100 foot necounting ye hand in spouting transverse, is put also into vapours.

It may be objected that if we shoot water in cannon of a foot bore ye water would go further than 100 foot: but we do not agree to this for it will not go 100 foot as may be proved and experimented.

Tho this swiftness is so great no accessible reservatory can give a parallel: for since ye swiftness of ye water wch goeth out there, makes 100 foot in a second as do ye bullets, Let us suppose that ye reservatory be 10000 foot heigh, and that ye swiftness of a globe of water of a foot makes in falling 13 foot in a second it shall make 26 foot horizontaly. ye product of 13 by 10000 is 130000, whose square root is about 360; as 13 to 360 so is 1 second to 28 near. If we suppose therefore that a globe of water of a foot is accelerated according to a series of odd numbers, wch

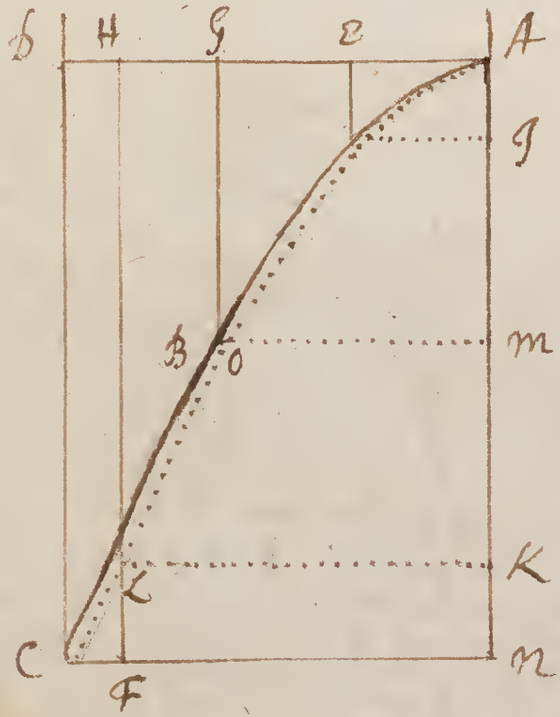
it cannot do however to a moderate distance, it will fall 10000 foot in 28 seconds, and make 20000 foot horizontally by a swiftness equal to ye swiftness acquired in 28 seconds and in one second about 714 foot wch is a swiftness less than that produced by ye gunpowder in ye cannon. but as there is accessible place of 10000 foot high, we cannot see ye effect of these spouts of water, besides that height of 10000 foot would give thro a hole of a foot 6452 inches neer which would make a river too considerable to be upon so great a height.

we must therefore believe that ye greatest spouts ought not to go to 300 foot; for about 6 inches diameter and ye conduit ought to be 20 inches large, and it would give 16128 inches, wch is also a too great quantity of water, and so it must be reduced to 100 foot high and to 12 or 15 lines of passage; for tho it should go 150 foot, it would appear very little higher to ye sight when we should be at 20 foot distance.

DISCOURS II

Height of obligue spouts and of their amplitudes.

The spouts we speak horizontally or obligneley as in ye figure following describe a crooked line wch is a parabola or semiparabola whereof Torricelli hath given ye demonstration after Galileus: but we must abstract ye resistance of ye air, yet if ye spouts are weak & crooked line shall be sensibly parabolic because that ye air resists a small swiftness and that ye acceleration of ye swiftness wch fall, or ye diminution of that which spouts is made sensibly according to odd numbers.

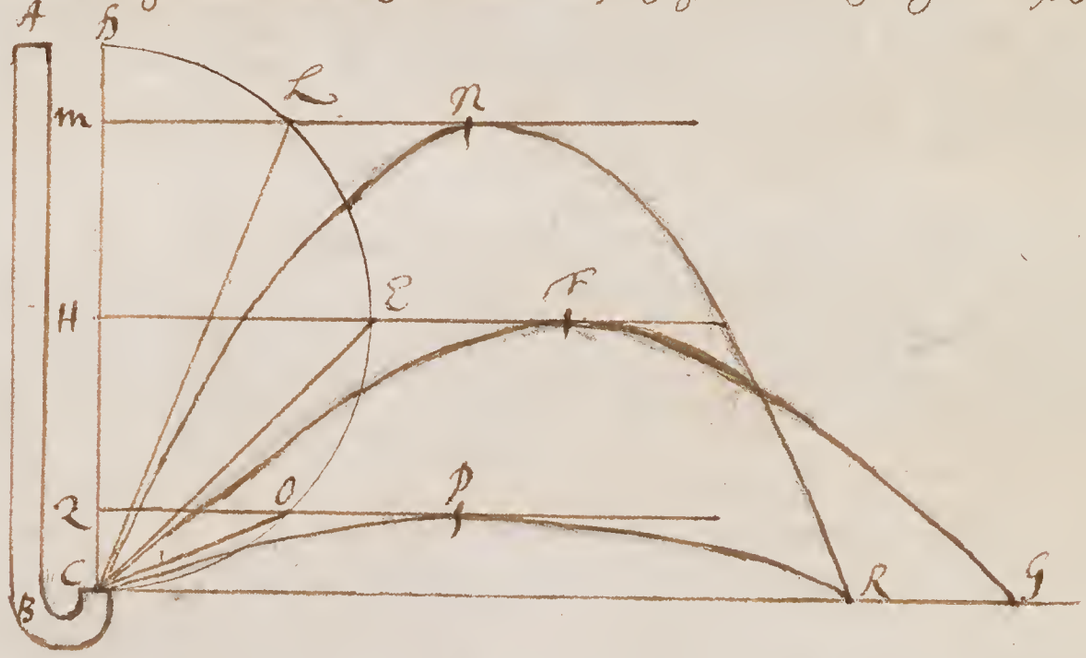


and also in ye moderate swiftness of ye spouts, their curve approaches very near a parabola because that it on one side ye horizontal direction is retarded a little and doth not go with an uniform motion, so ye acceleration doth not go at ye end of ye fall according to odd numbers, but it is retarded by ye resistance of ye air as is explained above, and so one of these faults recompenses ye other as is seen in this figure, where the true parabola is A B C, it is in 3 equal small intervals of time a thing moved runs horizontally ye 3 equal spaces AE, EG, GD, and that it runs in descending Ag in ye first time gm which contains 3 times Ag in ye second, and at ye 3 mn wch contains 5 times Ag. but it ye shock of ye air makes a thing moved go but to H instead of going to b in these three times, or that ye shock of ye air will hinder it to descend in ye same time to n, and it will go but to K and drawing ye parallel KL wch shall cut ye F in L a little within ye curve A b C ye curve line A o L wch shall be described by that motion will under ye proposition (though not strictly true) shall trace another parabola inferior to ye first A B C, from this property of body wch move in ye air we deduce ye following problem.

Problem 2

The mean height of a reservatory being given, and a spout being oblique to find where it will touch a horizontal plane.

Let A B be a pipe of a reservatory C a passage, c b a line parallel to A B, b E C a semicircle, of wch H is ye center; Galileus and Torricellius have shewn that if ye direction of ye spout at ye going out of ye passage



is ye line c L wch makes an angle b c L with ye perpendicular b c of 45 degrees having continued H E perpendicular to b C unto F, so that E F be equall to ye semidiameter of ye circle H E, ye point F shall be ye top of the parabola C F G described by ye spout as it goes in ye figure c E shall be ye tangent of that parabola to ye point c; and c G ye amplitude of ye parabola double to H F or c b.

But if we give another direction to ye spout as c L, we must fall perpendicularly L m upon c b and m L being double to m l, ye point n shall be ye top of ye parabola wch that spout shall describe, whereof c R shall be ye amplitude equal to 2 times n h, ever ye same in respect of all other directions. whence it follows that if ye angle L c E is equall to ye angle E c o, ye spout at ye direction c o shall go as farre as that whose direction is c L; and 2 o p being equal and parallel to m L n p shall be ye top of ye parabola of that spout; and they both shall meet at ye point R in ye Horizontall line c G, since their amplitude c R ye quadruple of m L or double of m n, shall be common to both.

The spouts of bombs full of powder observe ye same rules: whence it follows that if we find by experience that a bomb whose direction is 45 degrees, goeth to 600 toises in length it will go perpendicularly 150 toises: for if c G is 600 toises, and that a bomb hath described ye parabola c F G, it will be elevated but to ye height c b wch is ye semidiameter of the semicircle, wch by consequence shall be 250 toises half of ye amplitude c G of ye parabola C F G: but we must consider that ye resistance of ye air changeth a little these measures, for there being more air to pass thro c F o than in c b, ye bomb will go a little nearer ye point b in proportion than ye point G. and for ye same reason if ye direction of ye bomb was c L and that it should fall at ye point R it would go a little further by ye direction c o, since there is more air to pass thro

in ye parabola cnR than in ye parabola cpR. how are ye experiments
wch I have made with water wch ought to be more regarded by ye aim
than a ball of iron or a bomb.

In ye figure preceding Let us suppose ABC a pipe of 6 foot high
from ye surface of ye water at ye top of b in ye reservatory to ye passage C; ye direction
of ye spout was 45 degrees and by what we have said cG wch was ye amplitude of ye
parabola ought to be 10 feet: but ye spout was scattered towards ye end, and that
will approach nearst 10 foot was 9 foot 10 inches, and by consequence that spout
wanted but $\frac{1}{120}$ part that is to say 2 upon 120. but having made experiments upon
greater heights, ye spout diminished more of it amplitude to proportion for
ye greater resistance of ye air, and that diminution ought to be made in pro-
portion to ye heights of ye spouts, and so we must take ye double of the
perpendicular height of ye spouts to know their amplitude of ye parabolick
spout at ye elevation of 45 degrees

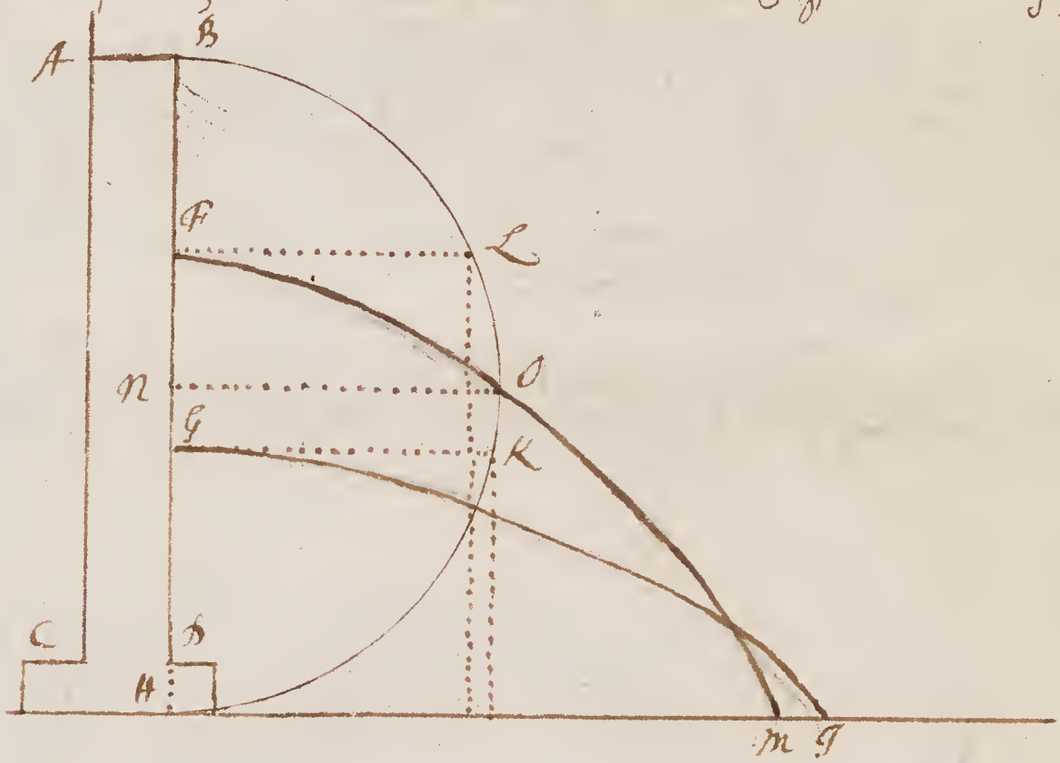
The spouts of quicksilver produce ye same but their ex-
tremity is scattered more than ye spouts of water, whereof ye cause is that ye
superior mercury BF slides upon ye inferior cE b by its incumbrance

on ye contrary ye mercury towards E descends by its weight and by ye shock of that
wch is above it; wch make ye drops of ye quicksilver become seperate one
from ye other between b and F from above downwards; but they do not scat-
ter in Largeness. and if we put our eyes in ye plane of ye direction of ye spout
it will appear but as a stream of ye same Largeness throughout, wch it hath as
its going out of ye passage because it drops not scattering at ye going out, ye nearst
ye eye covers all ye others wch are below in ye whole extent of ye spout.

To make by experience that ye heavier ye matter ye greater
ye parabola, I hung a ball of steel to a thread of 3½ foot Long and having
elevated it to an arc of 50 degrees I let it go, it returned after having mounted
on ye other side to 49 degrees 45 minutes; ye arc of 15 minutes wch remained
was 6 lines Large and by consequence it Lost but a Line and ½ or near in
falling to ye point of repose. I put afterwards a ball of wax of ye same gross-
ness charged with a small weight, so that its specific gravity was as that of
water; and having elevated it to 50 degrees it returned to 4 inches at the
second beating it Lost therefore 5 times as much by ye resistance of the
air as that of ye steel, wch is near in proportion as ye specific gravity of
water to steel.

when in a pipe ye holes are one above another, and the
spouts are horizontal, we may know ye Length of ye spouts upon an
horizontal plane by ye same rules in this manner.

Let A B c b be a cylindrick vessel or of some other forme pi=
=ierced in F and G, & water in it being always kept at ye height A b. H I is an
horizontal plane, and if we would know whether ye spouts F and G fall upon



ye horizontal plane H I: Let us suppose that ye side of ye pipe B F G H where ye
holes F and G are pierced is of Lead upon ye Line B H for a diameter having described
ye semicircle B L K H, draw F L G K perpendicular to ye Line B H unto ye
semicircle in Line K, and having made H I double to G K, and H m double to
F L, ye spouts will describe ye semiparabolas G I, and F m as hath been said
above: whence it follows that it n is ye center of ye circle ye spout wch spouts
thro' n shall go farthest since ye Line no wch is ye semidiameter
is ye greatest than all ye ordinates as G K, F L. and if we take equall heights
above and below n ye spouts will fall upon ye same point in ye horizontal Line H I.

If we would know in a vessel or reservatory A B c b what height
ye water is, we must pierce a hole in some place wherein ye spout goeth, draw ye Line
G H horizontal from ye point G, and by ye point G ye Line G H perpendicular
to I H, having cut ye G into two equal parts, whereof Let G K be one, find the
Line G B a 3d continual proportion after G H and G K, that Line G B is ye height
of ye water in ye reservatory above ye hole G, wch is but a generating & preceding
proposition, wch is easy to be seen if we suppose ye height of ye reservatory to be
H B above ye horizontal plane H G, and ye hole of ye spout to be in G: for accord=
=ing to ye 3 Lines G H, G K, G B are in a continuall proportion; wch agrees to
what Galileus hath demonstrated in his 4th proposition of ye motion of bodys pushed
and spouting, where he sayeth that halfe ye amplitude of ye parabolas of spouts
are mean proportionalls between ye height of ye semiparabola, and ye height
of ye Ligner from ye hole of ye spout:

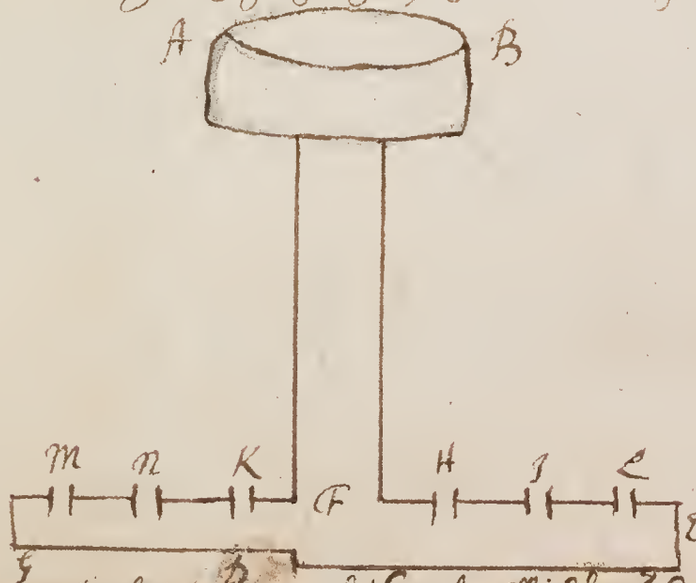
and having made some point

PART THE FIFTH
of the conveyance of waters, and of the resistance of Pipes

DISCOURS I
of the pipes of a conduit

Long or short pipes of swiftness of the waters is there stopped by the rubbing of wch I have made experiment in this manner.

A B c D is a pipe of 6 inches diameter and of 6 foot heigh the pipe c E is three inches large and the pipe G F one inch. we made at the points H, I, L 3 holes that in H was 2 lines, that in I 4 lines and the last in L in the other branch F G 3 holes K, n, m, were disposed after the same manner. According to the greatness of the holes in respect of the greatness of the pipe



A B c D the pipe A D being full we let go successively the 3 holes H, I, L the others remaining always closed, the mouth that was elevated the height that through next and that of H the lowest of the three: the other side m the great hole the lowest that of n a little higher and a little one K the highest of the 3 it will not be difficult to know the reason of these effects if we consider that there goeth much water thro the holes Land m, and that to maintain it the water must be much shitten thro the straight pipe than thro the large one, wch causeth a considerable rubbing, wch wrongs the swiftness of the water, and hindres its running swift enough to furnish the passage. but in the holes and K as the swiftness is 18 times less than when the water goeth thro L and m, the rubbing in the straight pipe is not considerable, and doth not sensibly hinder the mouth K more than the mouth H and they maint them as high one as the other: it appears also that if we diminish the holes I and n, for example each by a line, then the mouth thro I will mount less high than it should and that of n more high, because there will be less rubbing in the channel F G wch surpasseth the default of the resistance of the air, and in the channel c E that diminution of the rubbing should not be considerable, but the resistance of 4 lines, this hath confounded many

psons wch have made experiments in small pipes as F G, and they have
concluded as well as ye ~~water gains height~~ greatest part of ye makers of foun-
=tains that ye water goeth higher thrô small straight passages than thrô
Large, wch is contrary to reason and experiment except when ye conduit
is very streit:

The same thing happens when ye passages are long of 6 or 7
inches, or of 2 or 3: for ye spout shall be higher thrô a simple plate in ye
plate, wch shall be at a line or half a line thick: we may easily experi-
=ment it, if we shall have a pipe of 6 or 7 inches Large as A B C D, and that
in ye pipe E F sufficiently Large, there we may make two equal holes in ye width,

the first having a passage G I and ye other but ye thickness of the metal: for
we shall see ye spout thrô H will go higher than thrô G I, and ye more
we diminish ye height of G I, ye more the spout will approach to that at
H: whence it follows that ye long passages wch are put at ye mouths of
dolphins in fountains are very defective, ~~and other passages for the~~
~~water~~ and altho ye passage should go a little conical, ye spout
would nevertheless be attached: I have in an experiment: a pipe of
glass of a foot high and of an inch Large having its hole of 2 lines
reached to 10 ½ inches when it was conical but being made without a
cone, it reached to 11 inches.

According to ye height of ye reservatorys, and ye greatness of ye passages, I
made ye following observations.

There is at Chantilly a conduit of a pipe made with
pieces of oak wood pierced, ye holes are of 5 inches diameter. ye height
of ye water in ye reservatory is 18 foot, and ye conduit stopping to an
horizontal channel is near 104 toises. ye channel being let dry we
pierced one of ye bodys above and placed there a passage of 10 lines
ye water being withheld below, ye spout went to ye foot, so that there
was some small hinderance in ye long conduit and in ye passage: for

according to ye rules it ought to spout to neer 14 foot we put another passage of 80 inches longe in ye same conduit wch we made spout alone and it went but to neer 14 foot wch attributed to ye fault of ye passage wch was worse made than ye other. we after wards layd both ye passages together and ye spout of 12 lines went but to 12 foot and ye other but to 11 wch shews that a conduit of 3 inches large is not sufficient for a passage of 14 or 15 lines to that height of ye reservatory or for 2 of 10 lines each. we stopped ye holes and let go ye ordinary spout wch at ye side of ye channel and ye reservatory 2 or 3 foot heighe at ye same height of ye reservatory than ye last hole; ye reservatory was but 16 foot high above ye passage wch was conicall and of 12 lines diameter; it spouted about 14 foot right up a little more than is according to ye rules; wch happened without doubt from ye conicall passage as hath been shewn.

We made others experiments with ye same pipe of 5 foot (wch hath been spoken of) with its vessel on ye top of it foot. we fastned to the bottom an horizontall conduit of ye same largeness of 3 inches and of 40 foot long and we put at ye end a passage of 6 lines, and ye spout went as high as when there was but an upright pipe of a foot, ye spout produced also the same effects viz that after having first mounted to a certain height it diminished a little about a foot, and ye water being arrived to ye bottom of ye vessel ye spout was elevated anew, and went a little higher than at ye first and also an horizontal conduit of 4 foot long, and of 3 inches large doth not diminish a spout of 6 lines passage.

We have found also by experience that a passage of 7 lines went not less high than that of 6 lines at a reservatory of 52 foot with a conduit of 3 inches and also that ye pipe of 5 inches might have 52 foot of height for a passage of 6 lines: we may therefore take for a fundamental that a reservatory of 52 foot ought to have a pipe of a conduit of 3 inches diameter when ye passage is of 6 lines, and that ye spout will to ye whole height it ought.

To compare ye largeness of this conduit to what the reservatory ought to have and ye largeness of ye passages, we shall make this proposition

As ye number of ye inches which ye spouts give is
So ye number of ye inches of another spouts.
So is ye square of ye diameter of ye conduit of ye first
To ye square of ye diameter of ye pipe of the conduit of the second.

This rule is founded upon this that it is necessary that ye swiftness of ye water running be equal in ye conduits to ye end that there be no more rubbing in one than ye other: now it ye number of inches is quadruple ye surface of ye diameter of ye conduit must be 4 times as great to ye end that ye swiftness it ye pipes be equall:

According this rule if we would know what largeness a conduit must be of to have a spout of 100 foot there a passage of 12 lines we must take 52 foot height wch there a passage of 6 lines having ye pipe of a conduit of 3 inches diameter gives 8 inches and because according to ye table of ye heights of spouts ye reservatory of a spout of 100 foot ought to be at 133 foot. we must say as 52 is to 133 so is 64 ye square of 8 to 170, and ye square root of 170 being neer 13, we see that ye reservatory of 133 foot there 6 lines will give 13 inches and there 12 lines 52 inches of water: therefore as 8 to 52 so 3 ye square of 3 wch is ye diameter of ye conduit ought to be to 58½ of wch ye square root is 7½ neer wch shall be ye diameter of ye conduit sought, but for greater facility we may give it 8 inches.

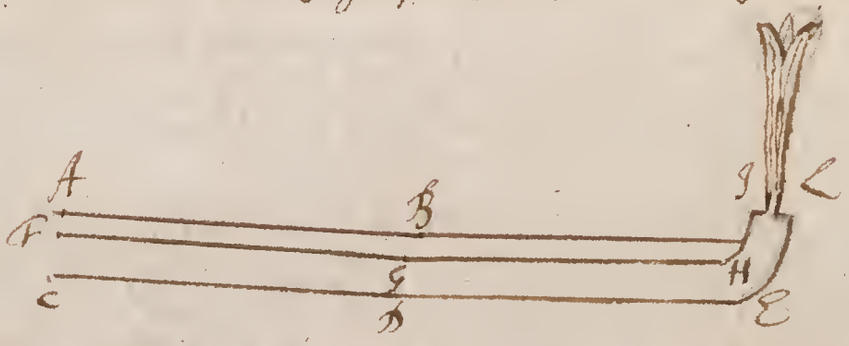
When ye passages are unequal and ye heights of ye reservatories equal, we need but make ye diameters of ye conduits in ye same proportion one to another, as ye diameters of ye passages: for then ye rubbings would be equal and ye walls will go no further would be equal pipes than in ye other, there is an example:

thwe 6 Lines if A pipe of 13 foot haigh give 1 inch thwo 3 lines: therefore
of ye same Largenes & water will go 4 times as swift and have 4 times
as much water: it is necessary therefore to make it go as swift as
ye forcing of ye diameter of ye conduit be 4 Lines as great, and then ye
root of that forcing shall be to ye root of ye other as 6 to 3.

There happens an effect surprising enough in ye conduit of
some pipes at chantilly; these pipes are of wood thrust one into another
pass thwe a small pond and afterwards thwe a long channel; whence it
happens that it will stop at a sluice ye entry of ye reservatory, and that
ye water running no more into ye pipe of ye conduit, ye spout of 14 foot
will not wholly cease, but it will continue to spout to near 2 foot with-
=out discontinuation, supposing that ye entry of ye reservatory was well stopped
we may attribute this effect to this that ye water running with a great ve-
=locity that of ye pond and ye channel doth a little open ye bodys of ye pipes
wch enter one into another, makes a small aperuation of water, like
as there is made an aperuation of air sensible enough when ye pipe
of ye conduit being void we let ye water of ye reservatory enter of a
sudden. for then ye air being pressed forces ye pipes and makes a passage
between those that are joyned one in another. now this aperuation
wch is made by little & little of water of ye pond and of ye channel, is great
enough to furnish the spout of 2 foot.

There happens also to ye same spout another extraordi=
=nary effect wch is, that if we put one hand upon ye passage and keep it there
for 10 or 12 seconds, ye water will not spout as soon as we take away ye hand, and
begins to be elevated by little and little to 3 inches then to 1 foot and after
to two successively in a considerable time. I have seen ye same effect
in a water wch ran horizontally in a pipe of copper: for having stopped
it with ye hand thinking that that water being retained a considerable
time, would make a greater effort and spout further, I was surprised
that there came presently almost no water out: but at last by little
and little it gained its ordinary force. see how I explain this effect.

descend to 8 toises from ye channel of chantilly wch hath a very small
if it was not pushed by ye upper water whose descent is steepe. now if
we suppose A B C D to be ye steep descent, and that ye channel is but half



full as from C B to F G, ye water will there run swift enough and will push
with ye same impetus that wch is in G H D E, and by ye motion it will have
acquired in ye way it will be carried swift enough to ye entrance of ye passage
I L wch it will violently fill and being shocked by that wch succeeds it will
be elevated to 2 foot, but when retaining it, it is stayed in its motion it
doth flow back towards B G D being elevated towards ye top of ye pipe
near to C, wch causeth that this water being in motion and its height
height in B being less than ye height of ye point L cannot make any effort
to turn ye spout till its motion begins to be made according to its straight
running wch is very slow.

We must avoid making ye pipes of ye conduit cut one another

of right angles: for ye water in its motion striking against that part of ye pipe wch is opposite to it, put it in danger of breaking, and is considerably retarded by that incumbrance.

If we would that ye Spouts should preserve their force for severall years we must make ye conduit a little Longer than they were made according to ye calculation: for there is heaped up in them dirt and filth wch hinders a little ye running, and also there are some waters wch carry with them Sphitic Atoms, wch joyning together form stones wch stopp up ye conduit: I have observed in ye Aqueduct at ye Cirque, and in ye Observatory where ye waters are separated a bason wch hath a cross spout in ye middle of half a foot high ye circumference of this bason is of copper whose there is made many circular holes of an inch diameter to know ye quantity of water wch is in ye Aqueduct, but by little and little there is heaped in these holes a stony matter wch at Last entirely stops them up ye water not being able to pass wch is very surprizing: for it seems that ye running water ought to carry away ye filth wch might be there heaped up. this done after ye same manner as ye snow is heaped up at ye Sides or upon ye branches of trees when there is night in a great frost; for ye wind carrying ye small particles or Atoms of ye Icy Waters in wch ye thick into some parts of these branches. and ye first retain and catch those wch follow, and at Last there is made a mass of 2 or 3 inches height. in ye Like manner ye water carrying along with it ye small stony Atoms wherewith it is charged in passing thro ye earth, some of them stick in ye pores of ye metalls and others wch follow are joyned to ye first according to their disposition and figure. there passeth many wch do not stick but in many years there is at Last heaped up enough entirely to stop ye holes as if it were a sufficiently hard stone, so that about every 50 years ye pipes must be taken away and new ones made.

When ye conduit of ye water in ye pipe shall be divided into many small conduits to make many spouts we must consider all ye inches of water wch all ye spouts together ought to give to determine ye Largeness of ye great pipe of ye conduit and afterwards be reduced by calculation to one hole of ye spout.

Example

The principal conduit is divided into 6 pipes of wch 2 have 2 lines passage 2 others 5 ½ 6, and ye 6th 8, ye height of ye reservatory is supposed to be 52 foot; likewise ye conduits are sufficiently Large and there is water enough in ye reservatory ye passages of 2 lines will give each 4 inches according to ye rules and ye table above those of 5 lines will give each 11 ½ inches that of 6, 16 inches, and that of 8, 28 inches, ye sum of ye expence of ye water of all ye spouts shall be 74 ½ inches, therefore according to ye rule given

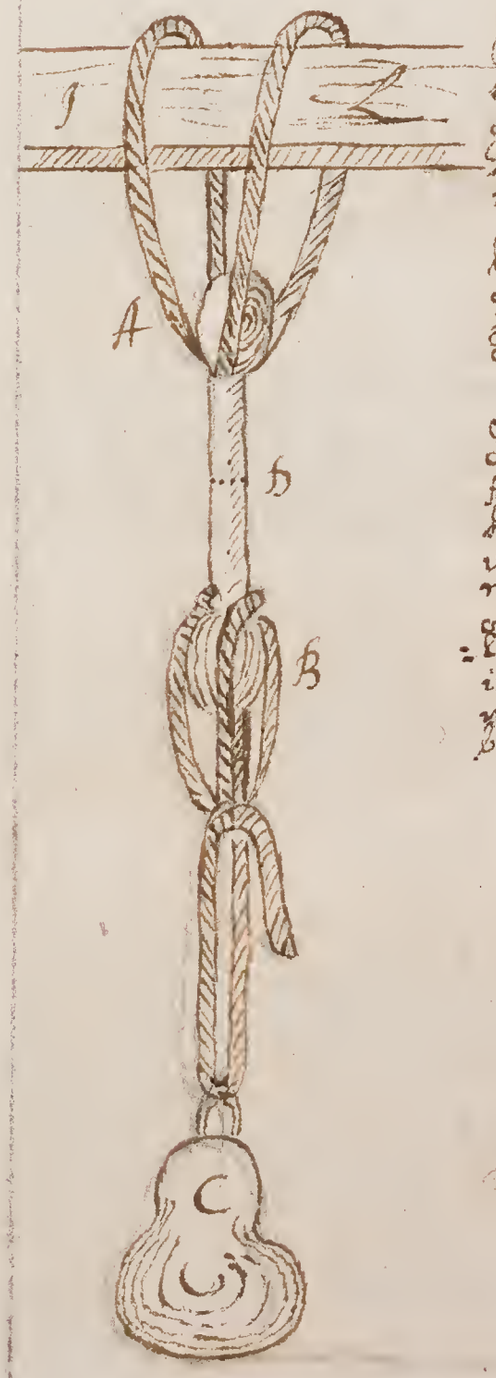
as 4 inches is to 74 ½ inches
so is ye Square of 3 to 168

be 13 inches whose Square root is 13 now ye first conduit must therefore will 3 inches Large, each of ye conduits wch have of a mid 13 lines passage inches and for a passage of 6 lines ye conduit shall have 6 inches and for that of 8 Lines it will have 8 inches. then all these conduits will give their spouts as height as they ought and if ye water wch furnishes ye reservatory be 74 inches, these spouts will go continually ye spout of 8 lines will go ye highest of all, and to know its height we shall find in ye table that a spout of 50 foot ought to have its reservatory of 58 foot three inches height and that of 45 foot ought to have 52 foot 9 inches; wherefore ye spout is between 45 and 50 foot, and very near 48 foot, and if we calculate for ye height of a spout of 46 foot we shall find 52 foot ½ inch for ye height of the reservatory: whence we may conclude that ye spout shall be little less than 46 foot:

DISCOURS II

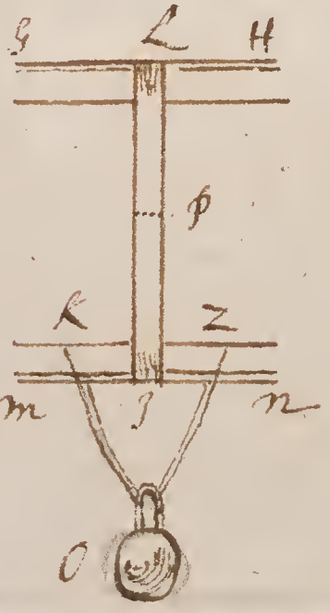
Of the force of pipes of a conduit and of the thicknes wch they ought to have according to their matter and of the height of reservatory.

When reservatorys are very high or there is made a conduit of water from very high places, the pipes of a conduit are often in danger to be broken principally if the conduit is made thro deep valys; and this is very tormenting, it often we have been at great cost first of the pipes break it is by the fault of the foolish of the thickness of the pipes: we would also avoid employing too much lead or copper to give great thickness to pipes when less will suffice, here is what we have observed about this matter

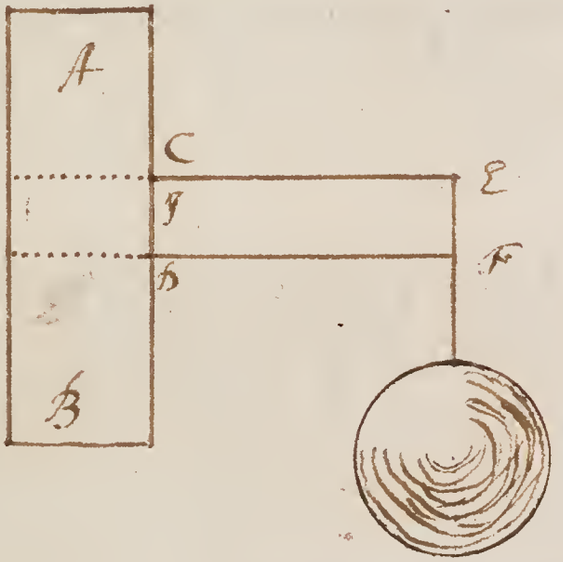


Solid and firm bodys whose their being broken by their small ties and tanglings of their particles one with another, there are some matters easy to be broken as ice, and other difficultys as iron, marble &c.

Of a solid we call that the absolute resistance or break it: so if we hang a cylinder of wood AB, by cords to a beam by means of its great head A, and that we hang towards its base B with cords a weight C of 1000 pounds wch may break a cylinder towards B or higher or lower by disjoyning and separating its interlaced parts, we say that its absolute resistance is of 1000 pounds. after the same manner we may know the resistance of a small band of paper, if we make 2 rings pulling to the band, and turning these 2 rings towards I and L two sticks G H, m n: having suspended at the stick m n the weight o by the cords K and Z if that band is broken as in p precisely by that weight than it shall be 4 pounds we say that the absolute resistance of that band is 4 pounds.



Galileus hath written a Tract of ye resistance of so=
=lids, where he gives ye same definition of ye absolute resistance and
explains cutw his meaning, & saith such a weight ought to have sus=
=pended at ye end of a solid fastned in a wall as ye wall is A B and ye



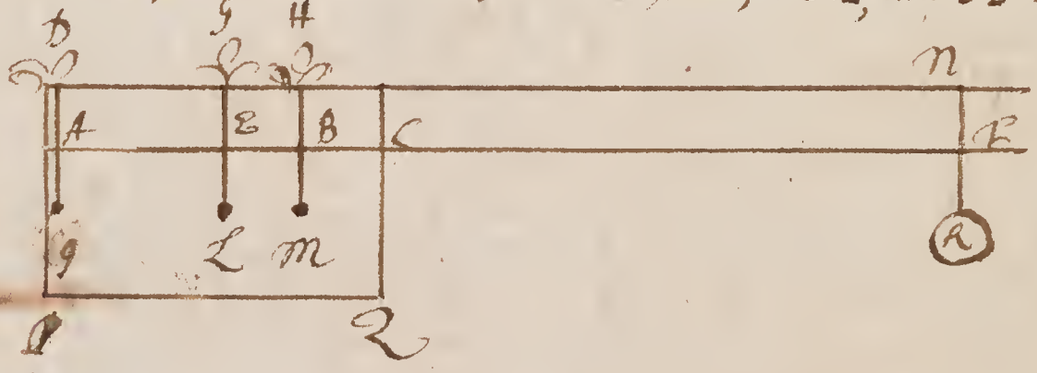
solid c b E F and that ye weight G is suspended in F by ye cord F G, he saith
that ye length F b is like ye arm of a leaver and that ye thickness c B
is as a centre always, so that if we would farthest a part in C and that
its absolute resistance be 10 pound ye weight G need only be a pound
and less part as if equally distant from C and b, there need
be but one pound in G because ye leaver F b would be than 10 times
greater than ye counter leaver b f; and because that he supposeth that
ye emptyness is made in ye same time in all ye parts of c B
which of same one between f and c, and ye others between B and f, he
pretends that we must consider ye augmentation of ye force of ye
weight according to ye proportion of F b to ye mean distance b f, which is
against many experiments wch I have made with solids of wood
and glass, where I have found that we must take ye proportion of b to
ye line less than b f, as ye fourth of b c or $\frac{1}{4}$ of c, or not of F b to
ye half of b c. To find this proportion and refute that of Galileus I
made ye following considerations.

I suppose first that ye wood, iron and other solid bodys have
their files and their bottoms parts interlaced one with another and that
they cannot be separated but by a certain force and that they make all
together ye firmness and resistance of ye body to be broken when we
draw them perpendicularly from ye top to ye bottom according to their length:
that these parts may be extended more or less by different
weights and that figure is an extension they cannot suffer without breaking
2 lines to be broken, and that a weight of 100 pounds can make that
extension a weight of 115 pounds will extend it but about $\frac{1}{20}$ a lines
that of 250 pounds but about a line &c and that so each extension
will make an equilibrium with a certain weight.

turning upon it's being supposed Let us consider the balance A C B
turning upon it's support C, charged at G and B, with a weight F making

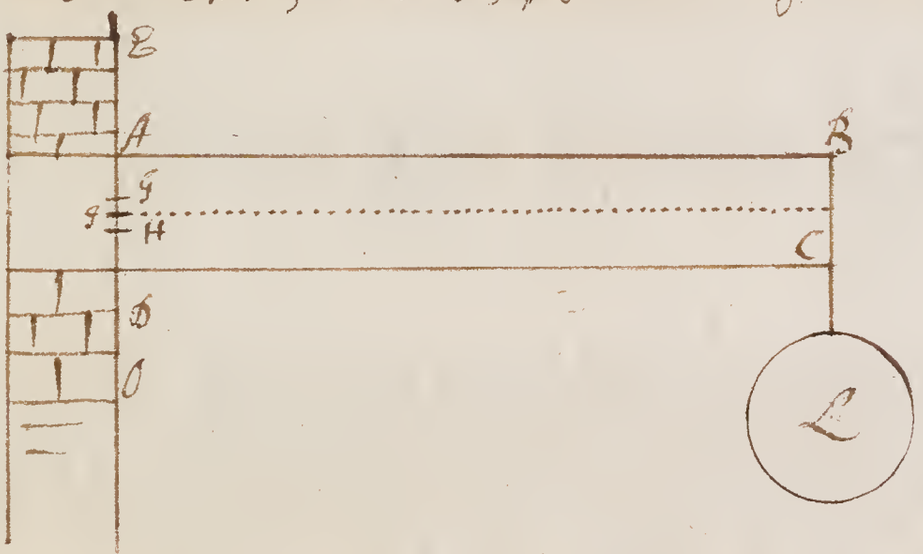
an equilibrium with G 3 equal weights G H & g distance B C is to C E
as 12 to 1, C B is double to C E and C A double to C b: now if G weight
G is 12 pound there might be a weight in F of 4 pounds to sustain it
since g distance B C is G triple of C A, there needs but 4 pound in F
to sustain G weight H, and 1 pound to sustain G weight g, and by that
means a weight of 7 pounds will make an equiLibrium with these
3 weights each of 12 pounds in G H & C: if therefore we add a small
weight in F & three weights will be elevated; and althô they are
elevated originally each shall be acted by a weight of 12 pounds acc=
=ording to their distance from C, but it is not the same in a solid that
is broken transversly: and to tell it:

Let us suppose F C to be 12 foot C A four, C E 2, and C B one foot,



and that G solid A b c n be joyned to G stable solid A C P Q, by G three
equal and equally strong cords B f, G L, H m a little touched wch pass a cross by
small holes in G solid A C P Q and are knit together on G end the other side as
is seen in G figure: now cause let us suppose that to G end each cord may be
broken, it must be extended 2 Lines and that G weight R hanging in F of 4 pounds,
may be strong enough to reduce it cord f b to that extension of 2 lines
and that adding a very little weight it ought to break, it is evident that there
must be 2 pounds to extend G cord L G above 2 lines, and only 1 pound to extend
after the same manner G cord H m, it G centre of G motion is in C: but because
that when G cord B f is extended 2 Lines G cord G L is extended but one Line and
G cord H m but ½ Line when we draw them all together it follows by G second
supposition that a weight of about 1 pound shall then make an equiLibrium
with G tension of G cord G L wch is but 1 Line and that there needs but 4 ounces to
make an equilibrium with G cord H m althô G total resistance of G last be
1 pound: and by consequent to reduce these 3 cords into that estate, it is suffi=
=cient that G weight K be 2 1/2 pounds, and that it there is added a very small
weight G cord B f will be broken and almost in a moment of 2 threw,
sinces they weight much less than G 3 together.

Let us also apply these weaforings to ye solid A B c b stretched perpen=
=dicularly in ye wall E A b o, and let us suppose that if we should draw ye right

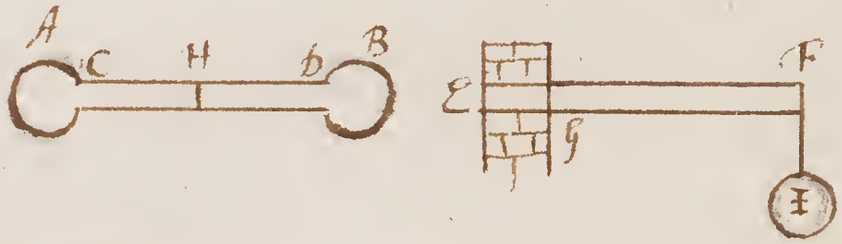


into ye base perpendicularly there might be 600 pounds to break it, & say that if A B is divided into 3 equall parts by ye points g, H and that c b, ye B H as 60 to 1 ye weight L need be but 10 pound to break ye solid when ac= =cording to Galileus it should be 15 pound, since c b is to b g as 60 to 1½ or 40 to a unite, and that 600 is ye product of 15 by 40.

To prove this proposition let us suppose as hath been ex= =plained above, that ye fibres towards A ought to be extended in very large parts to be broken, and that there must be a like extension to break ye fibres towards g, I, & H, it is evident that these last do not assist with all their force to hinder ye breaking of ye fibres towards A, and that if they assist in proportion to their distance from ye point b, and if there might be 16 pounds in L to break ye fibres in A, there needs only 12 pounds to break ye fibres in g & to break ye fibres in I, and 4 to break ye fibres in H, but because that when ye fibres in A is broken, ye fibres in g shall be extended but 12 parts, that in I but 8, and that in H but 4, this makes another like proportion, and so instead of 12 pounds to break ye fibres towards g, there needs but 9 pounds & ½ of 12 and 4 pounds to break ye fibres towards H. now 12 is ye mean proportionall between 16 and 9, and 4 between 16 and 1, and by consequence these numbers 1, 4, 9, 16 being squares if we conceive ye length A b to be infinitely divided, ye resistances of all ye fibres would be in proportion as a series of squares from a unite, but if we take such a square numbers as we please in a series beginning at ye unite 3 times their summ less by ye triangular numbers wch corresponds to ye last terme of ye proportion, shall be equall to ye product of ye greatest square by ye number of ye proportion beginning with a cypher, and that triangular number exceeding shall be to ye last product according to this infinite proportion 1 1/2 1/3 1/4 &c therefore this excess to infinity shall be a nothing, and by consequence all ye squares to infinity shall be together but ⅓ of ye square equall to ye greatest adding 1 for ye first term of ye proportion, like as if we take ye following proportion 0, 1, 2, 3, 4, 5, 6 &c ye summ of all these numbers is ye half of ye greatest by ye number of ye proportion:

To prove by induction this property of a series of squares let us take ye unite such is ye first square, ye triple of ye unite is 3, ye unite multi= =plyed by ye number of ye terms of ye progression 0, 1, is 2 wch is less than 3 by ye first triangular number 1 wch is 1/2 ye number 2, 1 and 4 together are 3 times 5 is 15, ye product by ye proportion 0, 1, 2, is 12 less than 15 by 3 ye second triangular number wch is 1/3 of 12 is 55 if ye summ of ye first squares 3 times 55 is 165 ye greatest 4 square 25 multiplyed by ye terms of ye progression, 0, 1, 2, 3, 4, 5, 150 less than 165 by 15 wch is 1/10 of 150.

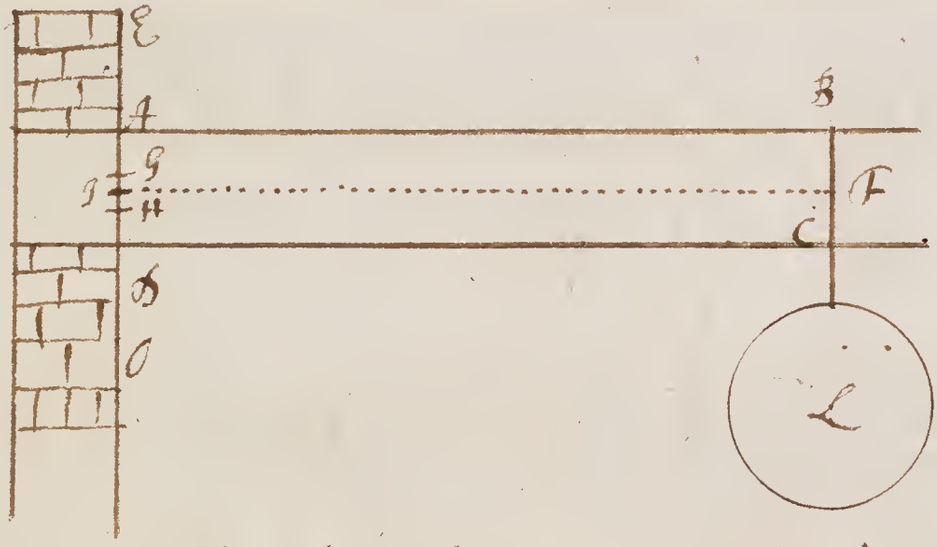
=ing. Accused two sticks of very dry wood to be tryed one of them wherof=
=of which A B had at its ends two small bowls, and ye west C D was uniformly



of three lines thick & ye rod E F was two and its whole length 3 lines thick:
I put ye end of this rod to E & put G into a small hole made in a beam and
fixed it exactly, and I hyld at ye other end, a weight of 6 pounds in F this
distance G F was 4 inches or 48 lines and by consequence was 48 times
greater than $\frac{1}{3}$ of ye thickness of ye cylinder call stick G F, since $\frac{1}{3}$ was but
of one line and according to Galileus ye proportion of ye weight was
augmented 32 times but ye stick was a little bent and ye distance was but
as 30 to 1 near, ye weight 1 being six pounds suspended at ye point F
broke ye stick at ye point G: now ye force of this weight was augmented
but 30 times it ought to make an effort but 180 pounds & product of 30
by 6. I afterwards suspended ye stick A B by 4 cords tyed to a small cord wch
went round ye neck b and was retained by ye bowl B b and fitted
after ye same manner ye other cords to ye bowl C A to suspend a weight
of 180 pounds wch ought to break ye stick A B if Galileus' rule were true;
but it did not break. ye experiment was made in ye presence of my Cavcavy
Roberval and Huygens, I added weight of 10 or 12 pounds one after another
and at last when there was in all about 330 pounds it broke in ye point
H. now if we take ye proportion of 47 to 1 (wch is $\frac{1}{3}$ of ye thickness) be=
=cause ye stick did bend a little before it broke ye product of 47 by 6 is 282
instead of 330 but it seems that if we had only put 300 pounds and let them
lye there some time as we did ye 6 pounds upon G, it would have broke
likewise, but lastly ye propulsion was greater than of 30 to 1, wch might
happen because that ye stick G F was bitten weaker towards ye point
G a little thicker: we likewise made ye experiment leaving a greater
thickness at ye two ends of ye stick E F, leaving only two inches from
G towards F that that part might bend it self a very little. I made use
afterwards of some canes of solid glass of $\frac{3}{4}$ of a line thickness and
I found always that we must take near ye proportion of ye length
of ye glass cylinder to one third of its thickness and in an experiment
which according to Galileus there needed but 30 pounds to break
a small glass we found particularly it was necessary to suspend
50; my Brother fitted ye small bowls of glass to two ends of a cylinder
to suspend it.

It may be objected that in wood glass or metalls there is nothing
to be extended before fraction; I confess that ye extension of glass is not
sensible; but that of metalls is easily known in that ye cords of musical
instruments of any metal are sensibly extended whence it follows that
a cylinder of an inch thick ought to be extended also, but there is need of
above 2000 pound weight to extend it, sensibly for since a bowl of glass
and steel is sunk by 6 foot and always into ye first figure it may be ex=
=tended also. If we let fall a cylinder of dry wood of an inch thick=
=ness upon a flat stone it will rebound, and by consequence hath a
spring, and its parts suffer extension and compression; and because
experience shows that a small stick that is bended to be broken is
first extended towards ye concavity of its curve, it is necessarily extended
towards ye convexity before it is broken: whence we may con=
=clude that it makes an effort to break ye compression towards the
concavity.

we may conceive that being supposed if B C b is a thick Iron wire fastened in a wall



by ye weight L those wch are near to b more than those towards B, and that from B to A they are extended, as hath been explained, and we may apply the reason to ye cords at ye part IH; whence it follows that as ye length AB is to ½ of ye thickness of A so shall a force twice of ye weight L, wch engendred to breake ye solid, and as there is need of greater force to pull ye parts towards b than towards H, if we suppose that that force is diminished according to a series of numbers from a unite there will be moreover need of the same proportion of ye length AC to ½ of ye Largeness b of to make ye rupture, and as it is probable, that these pullings whilst as much as ye extensions and that there is need of ye same weight to make them these extensions, and these compulsions part of ye force of ye weight L acting a third of ye thickness A to ye third of ye thickness b whose whole shall be equal to ye third of the whole thickness A b whence we follow ye same thing as to all ye parts wire extended: therefore to undo ye extension towards ye point A to a rupture, it is necessary that ye weight L be a little more than 10 pounds to break ye solid A B c b, if ye length cb is to ye third of ye thickness as 1 to 30, and that there is need of a little more than 300 pounds to break it by drawing it downwards: the ye same thing ought to happen in respect of ye effort of ye weight as it ye parts between B were extended as supposed.

I have experimented with my Tubin that a thread of glass of a Line thick and 4 foot long was extended ¼ of a Line without being broken, and lifting it upwards to its first length it regained its first extension we extended also 3 of ye same thickness wch broke being extended to 1¼ Line. to know if there was at ye two ends of each thread a bowl of glass of two or 3 Lines, we engaged one of these bowls between two lenten hooks stuck into ye end of a table almost to their halfs, so that pushing them during strongly we could not sensibly shake them, and by consequence ye glass end of ye thread being engaged by ye bottom of ye lenten could not approach towards ye other end of ye table, there was 3 small pinn holes made to discern ye elongation, ye thread was held upon ye table at its length, but drawing it moderately with ye hand, and drawing it strongly to ye second hole, and drawing it yet more to ye third, and a little relaxing ye effort it would return to ye 2d or 1st hole: to do it was necessary that one of its ends should be pulled into a hole of a small piece of iron and that ye other should be tied to 2 or 3 small cords wch being joyned together made but one, wch was wound about a peg of a lute or some other instrument to extend ye thread by turning by little and little. there was made marks to know ye elongation, and so we might make ye thread of glass like a cord of a virginal.

concerning ye resistance of solids these trials may very well serve Architects how ye beams and joynings &c.

A cane of glass of $\frac{5}{3}$ of a line thick is broken by its proper weights at 6 foot (Dr Gailleo)

A cylinder of black mauble of 5 lines diameter sustained horizontally 190 pounds that is to $10\frac{1}{2}$ pounds at ye distance of 48 Lines, & forasmuch as $\frac{5}{3}$ is $\frac{25}{15}$ its product by a foot Long or 144 Lines is 1600 or 400 Lines therefore a beam which 2400 cubic Lines, as 14 to 11 so is 2400 to 1886 Lines, and because a cubic inch or 1728 Lines weighs 2 ounces, dram, 1886 Lines shall weigh about 2 ounces 3 drams.

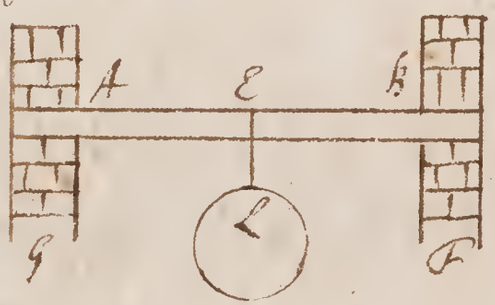
The shaft of 6 ye length of 6 feet is 72 inches or 432 lines as the third of $\frac{5}{3}$ of a Line viz $\frac{5}{9}$ is to 432 so is 2 ounces $\frac{1}{2}$ to 1814, wch divided by 16 ounces gives 113 pounds 6 ounces wch ought to be ye weights to suffocate perpendicularly by that cylinder of glass of $\frac{5}{3}$ of a Line.

A rod of glass of $\frac{1}{3}$ of a line thickness and 12 inches long being placed upon 2 rules 9 inches distant one from ye other and of an inch large and thick; and being charged at ye middle with 13 pound suspended by a cord it broken in ye middle: a like rod placed after ye same manner but fastned by its ends between ye two rules and 2 small flat pieces of wood of ye same largeness as ye rules, is broken by 3 pound 1 ounce hung at its middle & a bruise is made at ye two ends 1 joyned to ye rules and likewise one of ye ends was broken 3 lines within ye rule then ye point of support; so that we may take it for a rule that ye two extremities next ye supports are broken in this last case and by consequence there is need of twice as much force as when ye extremes are free and it is broken in ye midle.

A like rod placed with its midle upon an edge of a knife we put spanish wax towards ye ends to hinder ye slipping of ye cords wch should sustain ye weight and to mark their distance (wch was 9 inches) there needed but $1\frac{1}{2}$ pound and about 3 ounces to break it, that is to say that having put al each end 2 weights each of a pound less by 2 ounces and $\frac{1}{2}$, it was broken 3 lines from ye edge, there was a while mark to mark ye middle of ye rod.

A round blade placed by its end in a hole obliqne from below upwards supported 8 pound and a small plate of iron &c:

It is manifest that if a solid AB is broken by a weight E suspended at its midle E; being supported by ends upon ye two rules A and B, that it ought to break also if ye support if in E and ye two powers in A and B equal to one another and both together to ye force of ye weight E since it is always ye same effort wch is made in E. Galileus hath demonstrated that ye same weight wch breaks it in E will break a solid of ye same thickness fastned in a wall to ye point A if its length be equall to AE,



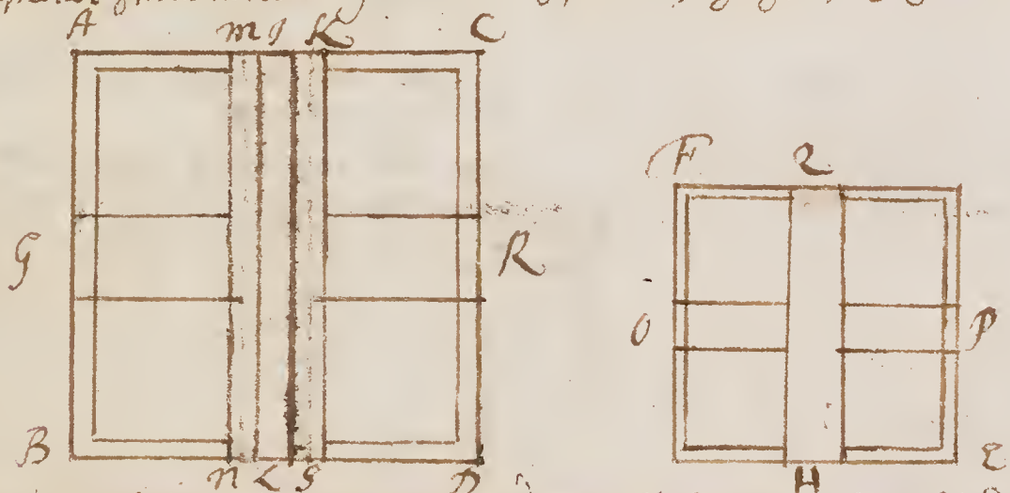
whence follows what I have often found by experience viz that a glass plate AB of 12 inches long placed and supported by its ends being broken by one pounds 10 ounces and 5 drams is also broken by 3 pounds 5 ounces 4 drams when ye ends are inserted in ye supports, because they then ought to break in A and B joyning to ye supports and because there resist by their 2 ends twice as much as E acts by its end A, there must be a double weight in E.

The same author also demonstrated that if ye supports are in a double distance ye half of ye weight wch was in E will suffice to break ye solid whereas ye reason is that ye lever becomes 2 times as long, and weight by consequence hath 2 times as much force ye counter lever not changing; but if ye solid is twice as thick there must be 4 times ye weight because one side there is twice as many parts to disjoyn and so ye force of ye lever is half diminished, wch makes that ye weight ought to be quadruple, and generally ye weights ought to be in a double proportion of ye thickness.

if we have a flat square of wood glass or some other fragile matter placed upon a square so that its extremities be strongly moved towards us as when we thrust a glass square into a [illegible] square frame & some weight distributed thro' out its whole extent wch will break it will break any other square of ye same thickness of what largeness soever:

Demonstration

A B c b is ye square wch holds fast ye square of glass; & F is another square smaller holding another square of glass of ye same thickness;



I say it will sustain ye same distributed weight thro' let a small band of paper 2 H be placed upon ye small square and two legs of callculation let ye band 2 H in ye other square be double ye length of 2 H and of ye same largeness and thickness it is evident by what gallileus hath demonstrated, that if we put a weight in ye middle of 2 H precisely sufficient to break it, ye half of that weight placed upon ye midle of I L will break it, but if we double ye largeness of I L and that ye band be m n K S, there must be ye whole weight to break it: for ye lever will remain ye same but it will have twice as many points to dispose; and if we distribute ye first weight along 2 H it must be double to break ye band 2 H as hath been proved by ye same author: therefore ye weight must be also double to break m n S K double of I L; but if we add cross ribs another band up to ye same square, we might double ye weight wch have confirmed by experience: for a simple band being broken by a little less than 2½ pounds, being made in a cross it required a little more than 4 pounds 11 ounces, wch is somewhat less than a double which may proceed from hence that ye square in ye middle was not double it: we therefore put another band cross wise of ye same largeness as I n it will carry ye same weight as ye cross P O 2 H, and if we continue to make these crosses larger in ye same proportion that of ye greatest will support always ye same weight distributed, and at last we may continue them till there remains but very small squares at ye angles of each square: whence we conclude that if we divide ye two squares ye same effect will always follow, and ye like in all other proportions: for ye square of ye middle of ye small makes ye cross to bear but a weight double to what ye band drawn, so ye square of ye great one will produce ye same effect.

These rules serve for solids whose mates are fragile, as wood, glass, marble steel, &c.

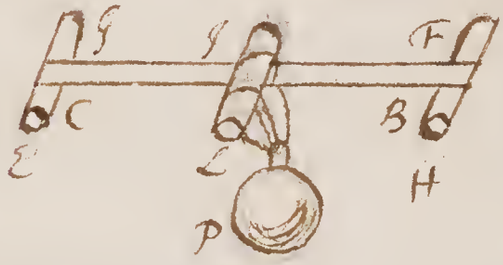
But for supple and pliant matters wch break only by traction as paper, tin, cords &c there must be other rules of wch have is ye principal:

Rule

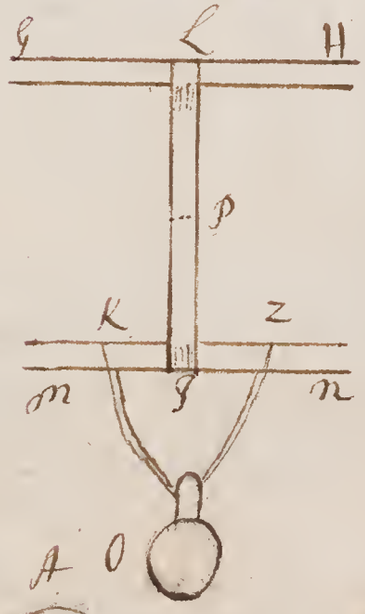
For those solids wch are simple
Bands of paper, tin, and other ye like matter are broke equally be they long or short.

Explication.

=outs E G, F H being of ye length C B there is put a small stick upon the
B C is a band of glued paper or Tin, nailed upon two sup=



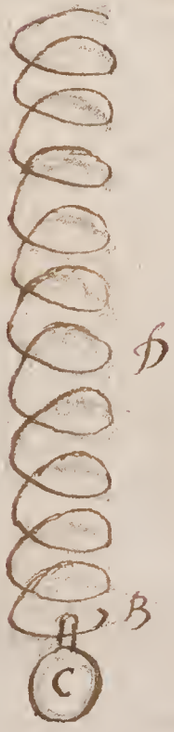
middle of the band and there was tyed at ye ends which passed a lit=
=tle beyond y paper cords to car=
=ry ye weight P; for if we should put a cord upon ye band of paper, it would wrinkle it or cut it; the band being of paper of six lines broad was broken by a weight of tenn pounds.



A little band was broken after the same manner when the supports were less distant from ye middle and when ye ends being wound about ye two small cylinders y H m n, there was tyed a weight to ye low=
=est cylinder by means of two cords as is seen in ye figure the band was bro=
=ken also by a weight of 4 pound.

Some object that the cord K Z carry one part of ye weight and that its weight is not employed to break ye band; but it is evident that ye band carries all that wch is below it, whether the cords are stirred or not: to prove it I have made ye following experiment.

A thread of copper turned spirally and sustained by the hand in A having ye weight C suspended at the end B was extended after a certain manner by this weight more or less heavy, but all ye spirall dis=
=tances were perfectly equal, and when we held our hand at b, ye distances remained ye same without chaning, which shewed manifestly that ye extension of ye upper spires when ye suspension was in A did not hinder ye force of ye weight in respect of the inferiour spires. The same thing happens to a cord which supports a weight: for all ye parts suffer ye same extension without that superiour diminishing extension of the inferiour or the inferiours that of the superiours, and a long cord and a short support always ye same weight unless it sometimes happens that in a long cord there is found somewhat wherby it will bee sooner broke than a lesser



The same things happens to bands of Tin for in a long one there may be a defect wch may not be in a shorter and if we take from it ye part wch is broken, it will support a grea=
=ter weight because ye defect was taken away: I have made several experiments.

being broken & is broken by 136 or 128 and being drawn downwards is not broke at 120 pound, but is broken at 123 at a place where it had some flaw we judged that it had supported more if it had been drawn very streight and there had been no default.

A band of Tinn of 3 lines $\frac{1}{4}$ Lange supported 100 pound without breaking it by putting in other weights.

A band of Tinn of 4 $\frac{1}{2}$ lines Lange carrying (a Tanx) of 5 inches in a triall square is not broke by 180 pounds, we did not finish

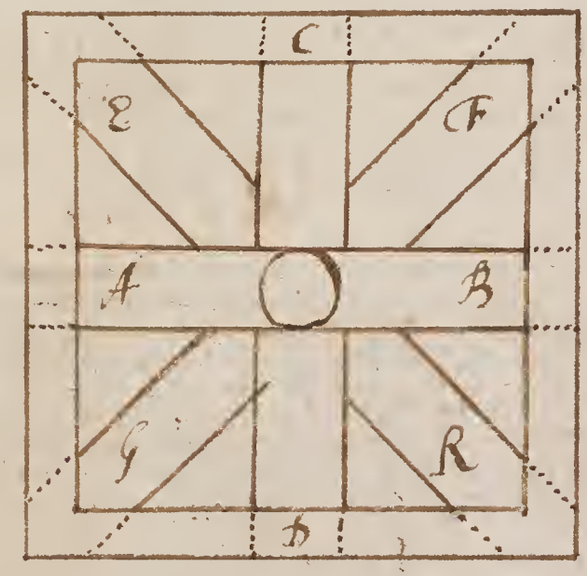
A band of paper of 6 Lines Lange being pushed by its two ends upon ye two opposite crosses of a square frame of 6 inches in ye work is broken by 4 $\frac{3}{4}$ pounds and there might be 4 ounces added to break an equal one drawn downwards. 2 others also of 6 lines were broken by 4 pounds keeping them $\frac{3}{4}$ of a minute with ye weight as well in ye great square as in ye little one.

Another band of paper of ye same power of 6 $\frac{1}{3}$ lines Lange is broken by 4 pounds, it was placed upon ye same frame in like manner as ye other it had three cords wch carried a small box and another cord passing below wch was sustained on ye top by a small stick, we put into ye box by little and little weights till ye band was broken. there was glued of this paper in ye great square of 9 inches within and in ye small of 6 inches after ye same manner as when we make paper windows we placed in ye middle of ye great paper a round leather of 3 inches 4 lines and upon ye middle of ye leather a lead weight of 4 pound wch was but 2 $\frac{1}{4}$ inches Lange at ye end wch was placed upon ye leather, we heaped up many weights upon ye first, and ye paper did not break but at 42 pounds.

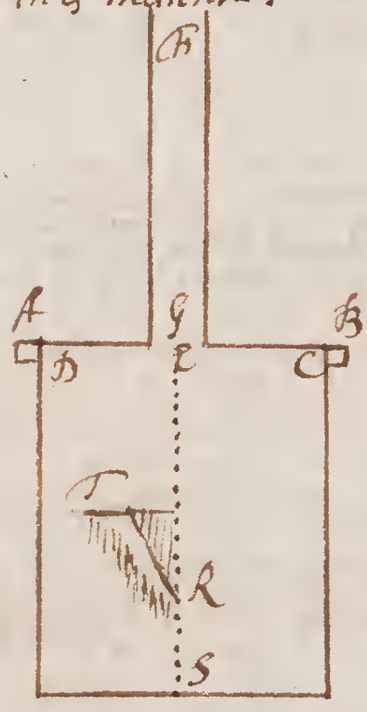
but its leather was but $\frac{3}{4}$ inch Lange upon wch we put ye same first weight.

The other paper upon ye small square broke at 34 pounds,

3 bands of paper To compare these experiments one with another and with trams being 9 inches and ye base of ye weight 2 $\frac{1}{2}$ inches So that ye leather was not quite held fast at ye sides, and we may suppose ye Largeness of ye band wch occupied ye diameter was 3 times as great as that of the band of 6 Lines wch supported 4 pounds and taking another band a cross CD of ye same Largeness it first AB sustained 28 pounds two of ye quintuples of 4 pounds these 2 would sustain 40 & 2 pounds more were sustained by ye 4 diagonal bands EK, GF, wch helped very little ye above said reason in respect of the cords because they are longer than ye others and are not extended their whole extent to be broken. in ye small frame ye band AB was but 3 $\frac{1}{2}$ times as Large as ye band of 6 lines, it ought therefore to sustain 14 pounds and the two in a cross 28 pounds the remaining pounds being for ye 4 diagonal bands and although this is more in proportion than in ye great, it happens because of the inequality of ye matter wch hath its absolute resistance less in one place than in another. but if ye bases of ye weights had been equal in the two squares of paper they should have carried ye same weight; Graphice in talk is made between ye weight and ye square of ye wood.



Mr Hawksbee having made many & like experiments I made many with pipes full of water: I made a pipe of 50 foot whereof I have taken about and having soddered it in a cylindrick vessel of a foot broad on all sides, we placed ye vessel upon 3 supports at ye ends. ye bases were plates of copper of a line thick and ye circumference was tinn-ed. The upright pipe of 9 inches height was soddered in a hole made at ye middle of ye upper plate and ye cylindric surface of tinn was soddered with ye plate in this manner:



A B represents ye diameter of ye plate, small ignarly C and D ye thickness of a thread of iron wch was wound & tinn-ed wch made a vessel neat ye plate and served instead to solder it there. E F is a pipe of tinn of 50 foot high, ye lower plate was soddered after ye same manner with ye tinn vessel as ye upper we filled with water ye vessel and ye pipe when it was at ye height ye plates were violently compressed by ye weight of ye water and as they acted like a brew-stocks and was G, and ye conservatory of ye soddering upon ye end of the thread of iron ye solder was broken by that effort, ye parts nearest G being separated first. The place unsoddered was 4 inches through which ye water ran, we soddered it anew and ye lower plate was also unsoddered as in ye experiment we made at the vessel where ye tinn being supported in ye plates was stopped within and well soddered, we augmented ye height pipe & it till it was 100 foot high and it remained full of water a long while but being broken, but at last one of ye solders of ye vessel was opened at ye bottom from E to R, and was wrought a crack from R to F. The plates were curved above an inch but their solder with ye tinn was not broken because acting like a brew as in ye first experiment turn more strong because of ye great effort of ye water. ye soddered part of ye tinn was stretched with it and by that means was not unsoddered. we kept that pipe a long time full to 80 and 90 foot; but it did not break; and because ye water 90 foot; but it did not break; and because ye water of 100 foot acted upon that vessel of tinn as it it was a pipe of that height and of a foot large as hath been proved in ye discourse of ye equilibrium we may hold for certain that a pipe of tinn of 60 foot and of a foot large will not break being filled with water.

afterwards I put a vessel of lead instead of that of tinn its thickness was 2½ lines at a foot large and 18 inches high but it swelled like a barrel towards ye middle of ye plate plates of lead of 6 inches large and of ye same thickness of two lines ½ ye solder advanced ½ inch upon ye plates and upon that wch was riveted wch found ye plates so they were an inch large or more they were above 8 lines height we filled ye pipe with water to 100 foot high, and ye two plates were bent bound above ½ inch but nothing broke: ye solder was elevated alle along with ye vessel and ye lead was too thick. It was as a porous lead wch had let some small streams of water pass as I once saw ye experiment in a vessel of 1½ foot and of 2 lines thick altho ye upright pipe was but 15 foot: Lastly to make an end of ye experiments I levered with a knife and filed ye vessel about 6 inches high and 4 inches large and when its thickness was reduced to a little less than a line in ye middle of that wch was filed then ye lead ye lead swelled in that place and there was made a crack of 3 inches height through wch all ye water ran out: we may therefore for surety make use of a pipe of 100 foot 12 inches large and of 2 lines thick or after ½ line if ye lead be good. See how we may obtain ye resistance of ye vessel we must consider it as a band of tinn by a foot large wch must be broken by winding: now this band is 24 times as large as that of three lines wch sustained 120 pounds, it ought therefore to support 45 times as much near and because ye water of ye pipe did weigh 5000 pound: for we must consider

A as if it was 1 foot large lo & height of 100 foot: and a cylindric foot of water weighs 55 pound wch multiplyed by 100 give 5500, 45 times 120 make 54 00, and by consequence y sum is just enough, and if y ladder had been good thro out y vessell had carried 100 pound on a foot of water, more we might consider that, we do not make y weight distributed thus out; if we would know y proportion of y resistance of ye pipes, we may follow these rules, supposing the plates to be strong enough.

Rule I

If y height of y vessel or vatory is double there will be y weight of twice as much water and by consequence y metal must be twice as thick in y pipe, that there may be twice as many parts to be separated. If y diameter of y pipe is twice as large it must be twice as thick: for so y same parts of the tinn shall be no more charged being made double.

Rule II

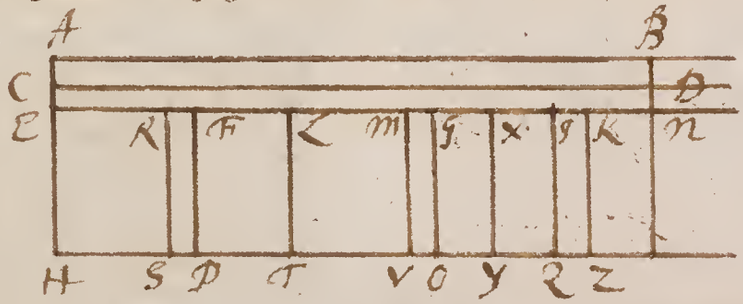
If y plates are less strong, and y rupture ought to be made in these supposing of cast iron or of some other weight and (as I am) matter when y pipes have 4 times as much height we must only double y thickness as it hath been proved above: for then y plate is broke as a lever and the centre = lever becomes twice as great and there is twice as many parts to separate, y same thing will arrive if y diameter is double: for it will have 4 times as much weight; we must therefore only double y thickness: whence these different plates may support y same weight, but y weight being quadruple we must double = culate as in y example above; we must double y thickness now y quadruple thickness of y plate, but when it is time or it appears very flexible y vatory is 4 times as high, it will have 4 times as thick, and if y diameter is double it will have yet 4 times more weight, and we might again quadruple y thickness, wch shall make it 16 times as thick: so if 1/4 line thick of copper can support a pipe of 60 foot high and 4 inches large, if y height is 240 foot, and y largeness 8 inches, there must be 8 lines of copper.

It seems better to make y pipes a little thicker than according to this calculation for it happens sometimes that there is faults in y matter, we have seen conduits of cast of 4 inches diameter and of 3 lines thickness where will found many pipes of those wch were joyned together to compose y conduit wch were broke because in spouting they were emptied and the matter was defective in those places y water also was seen to burst through y pores at y beginning but at last y pores were stopped by y filth of y water carried, and were afterwards of good service.

DISCOURS III

The distribution of waters

To part y waters into divers spouts and to know how to give to each wch may serve also for y distribution of y water of a source into many particulars, we must have a gage whose holes are square and not round.



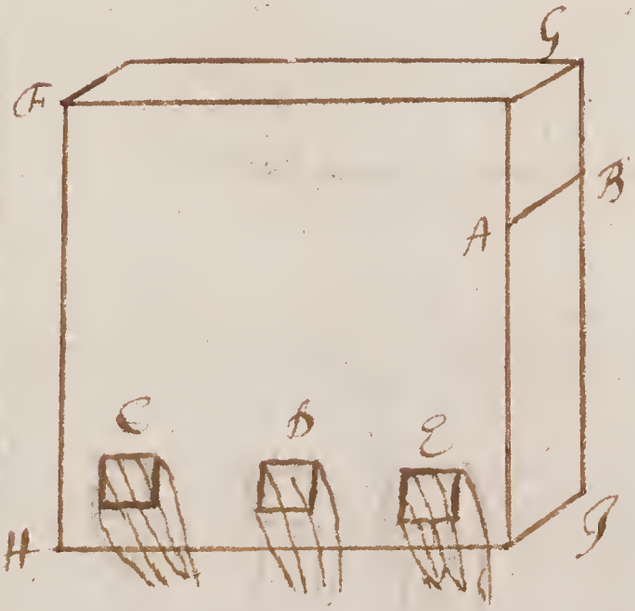
we must place y square holes about two lines below y surface C D in a straight horizontal line E N: now if we divide this gage into many squares equals of an inch as E F G H &c they will give more than an inch: for the

circular give 14 pints in a minute & squares will give a quantity wch shall be to 14 as 14 to 11 wch proportion of 14 to 11 is neer that of a square to a circle of ye same Longness: if therefore a round pipe gives 14 pints in one minute a square pipe will give somewhat less than 11 pints: for 11 is to 14 as 14 to 19 2/3; we must therefore divide E F into 14 equal parts, and if E R contains 11 to these parts of Long square E R S # shall be neer equall to a circular pipe and will give on pipe that if 14 pints in a minute, if the water of ye vessel wch serves for ye gage remains at ye height C D. we made afterwards many holes equal to E R S # under ye same line E N as R L T G L M V T &c and if we would give 1/2 pint we must divide one of these Long squares as O R G G into halt by ye line X Y and each half will give 1/2 pint that is 7 pints in a minute, and in all other divisions after some manner by taking 1/3 as I K Z Z or 1/4 &c. there will be also this advantage that if the water wch stumbleth at ye running be cast, and that in running it falls but ye third or 1/4 or 1/5 of ye height of the holes in proportion wch cannot be done when ye holes are round and if there is somewhat more rubbing in proportion in ye small holes then in ye greater that shall be recompensed by ye water succeeding better in a small running then in a great: if we would give 3 or 4 inches we must take three or four equal holes each equal to E R S # as E H V m for 3, but we must seperate ye holes a little when we give but an inch to each particular for their waters would be mixed if there was but 2 or 3 lines between them, & only of each pipe must be large enough to receive ye water of each division.

See how we may distribute a source in a town to many particulars

I suppose that ye fountain gives 40 inches of water in summer and 50 in winter and 45 at other times; we must make many reservatorys as C F G H B where ye water is discharged

In ye first wch shall be ye greatest we must permit ye water to rise to a certain height as A B where we must make a passage for ye water to run further, and make holes thro wch we would make ye first distribution as D E a foot below A B these three holes may be great enough together to let pass 20 inches and the 25 inches remaining may pass above A B.



It is evident that when ye water shall be highest & elevation of running water shall be greater above A B and when weaker less; but shall not be above an inch more: so that when ye water wch enters into ye reservatory shall be 50 inches there will pass thro about 20 1/2 inches thro ye 3 holes and there will pass near 19 1/2 when it gives but 40 inches we shall make ye same in regard of ye water wch will pass above A B as of that below and shall make small reservatory in some other part of ye town whence we may distribute to particulars of 25 inches and of 20 inches observing always to make ye holes 12 inches or at least 10 inches below A B. Lastly it will happen that in great waters there will remain 5 or 6 inches of water wch shall begin to run thick in some places less frequented for some hrs and that water will last but while ye waters are great wch we shall observe also in ye other conduits C D E. for it will have always some remaining wch should be for ye profit of ye town by making provision on stores of water wch are purchased along time with out ye clearing of any, and wch are wasted from time to time, yet shall be always distributed of 45 inches, except they are some times a little less or sometimes a little more:

Frontinus a Roman Author hath spoken of these conduits of waters after another manner, what we call an inch he calls a Quinaria, but that his quinaria was somewhat smaller; it seems that the manner of applying what he calls a calice at the bottom of which he had a small pipe of the wideness of his Quinaria cannot be fitt and it seems better to bring to one part of a Cubit 10 inches if there is need but of 10 inches for the particulars wch are there and discharge them into a long reservatory, where a gage was applyed as above, giving an inch or half an inch according to the design and when there is parts wch are in value but one line wch is 1/12 part of an inch or 2 lines wch is 1/6 part of an inch then we must make the gage otherwise than that above. In a small reservatory we let the water pass 6 lines above the holes and having made a square hole of 4 lines large, we took away 2/3 of that Largeness leaving the height of 4 lines wch gave the ninth part of an inch that is to say 16 lines, the half of that Largeness wch give 8 lines and 1/2 4 lines, or else we may make the water pass 6 1/2 lines above a hole of one line square then took taking away 3/4 lines for the value of a round line wch will give 1/14 of 14 pints to make a foot: If we double its Largeness it shall be 2 lines wch will give a mid in 24 hours and 12 pints in a hour and 3 pints in 1/4 hour; and to be certain that it gives no more now less than 2 lines; we must count the time in wch that holes fills a semisphere and it is in 18 seconds of measure shall be just: we must observe that little water be in channells of an inch at least, for this might be stopped up if they were broken and also during 10 years we might take that the pages are not filled with any slimy matter wch diminishe the their holes and in that case we must make them anew.

When the pipes of a conduit are not Large enough there is heaped up in the Lowest places very fine mud, wch the clearest waters oftentimes carry with them, wch becomes hard entirely stops the pipes, whereof it is convenient in the Lowest places to make holes from time to time for the waters to run out with violence wch will carry with it that filth provided it is not petrified.

It happens moreover that if we are obliged to make a pipe pass below some eminence, we must adde to the upper part of the pipe of the conduit another small pipe wch is called a vent pipe, this pipe hath a cock at a moderate height above the pipe of the conduit it is opened from time to time to let out the air, wch being drawn down with the water is gathered in the upper part of the pipe and well being compressed by the water wch presseth it gets out in bubles, and strikes violently against the pipes of the conduit that it many times makes holes, if it is not very strong to resist, and at last breaks it if it is of a fragile matter.

The End

D.